Chemical Engineering Progress

OCTOBER 1955

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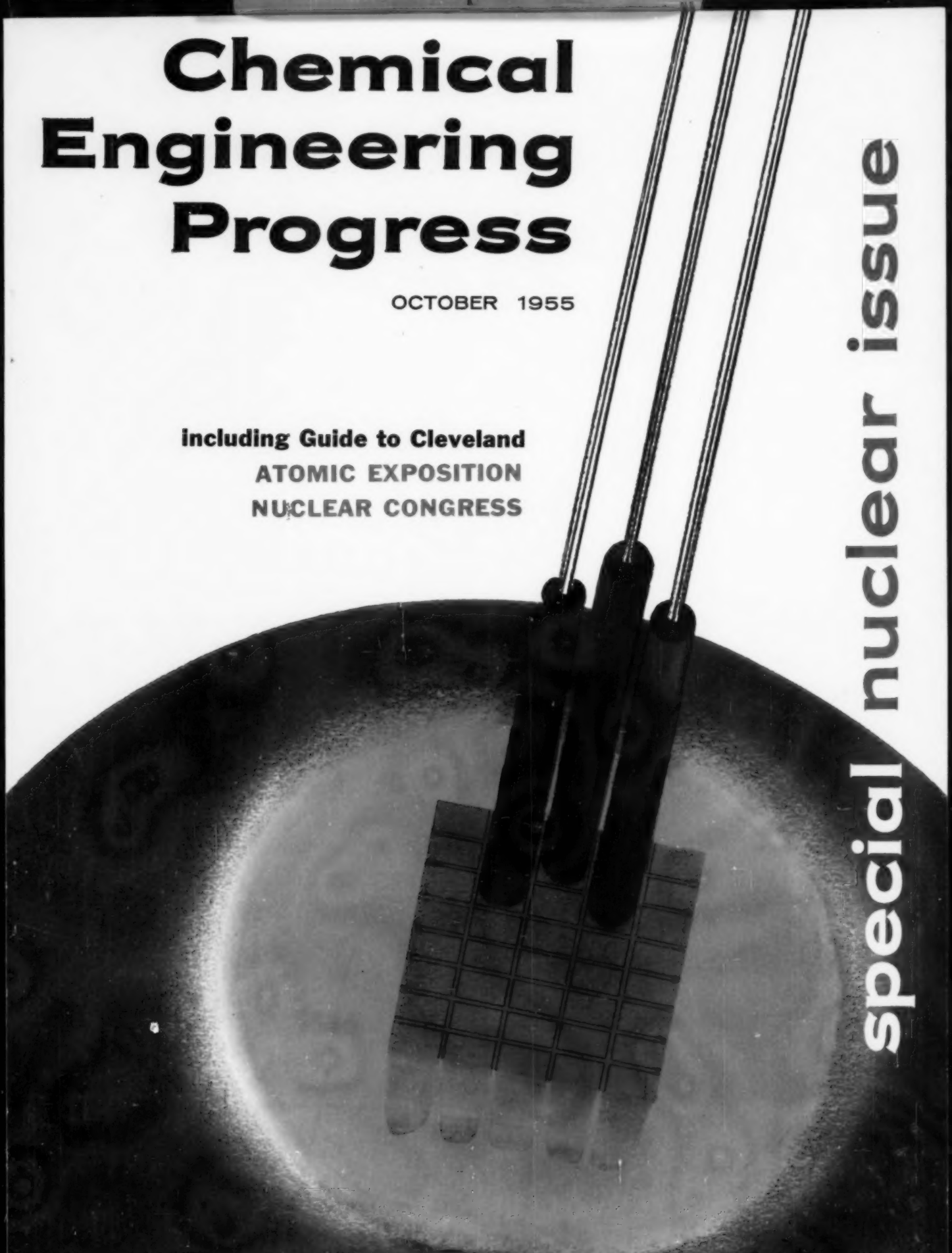
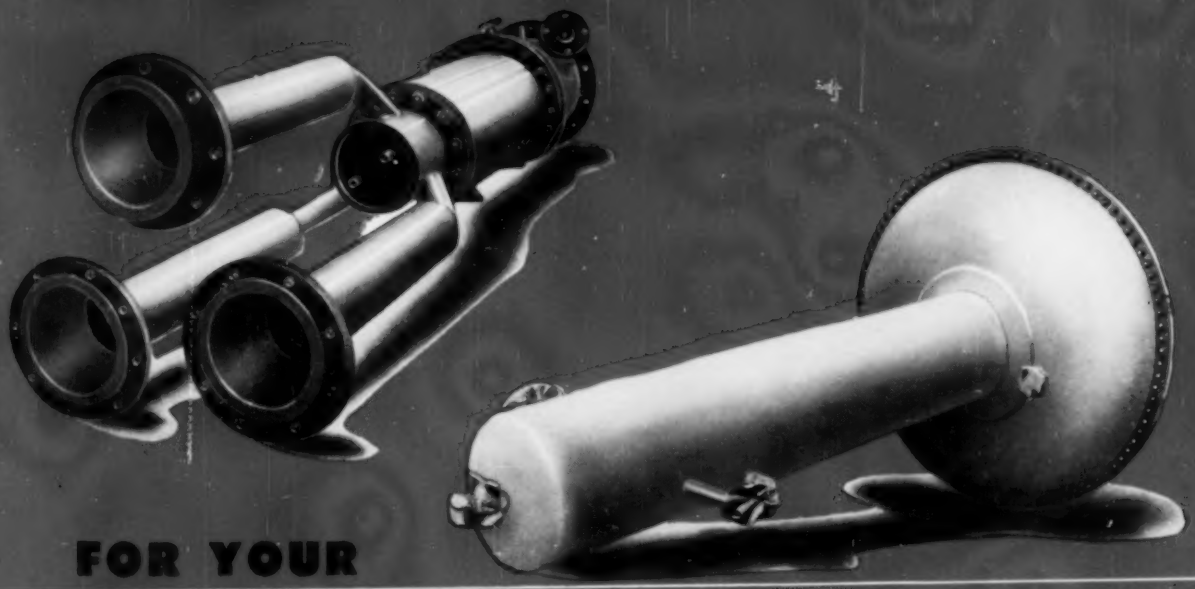


special nuclear issue

Detroit Program · Whitman on Geneva · metals & minerals · chemical fires · commercial reprocessors · Idaho Chemical Plant



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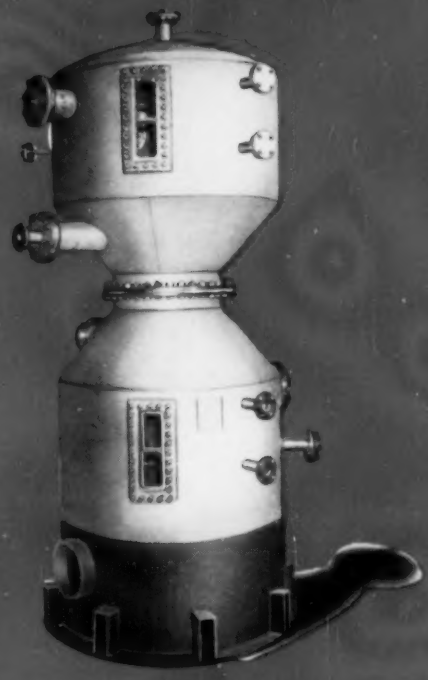

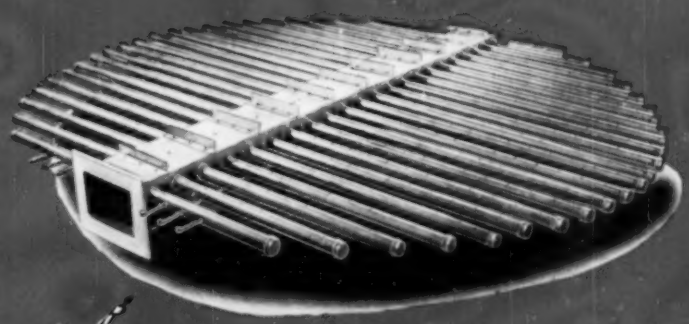

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Chemical Engineering Progress

OCTOBER, 1955 • Volume 51, No. 10

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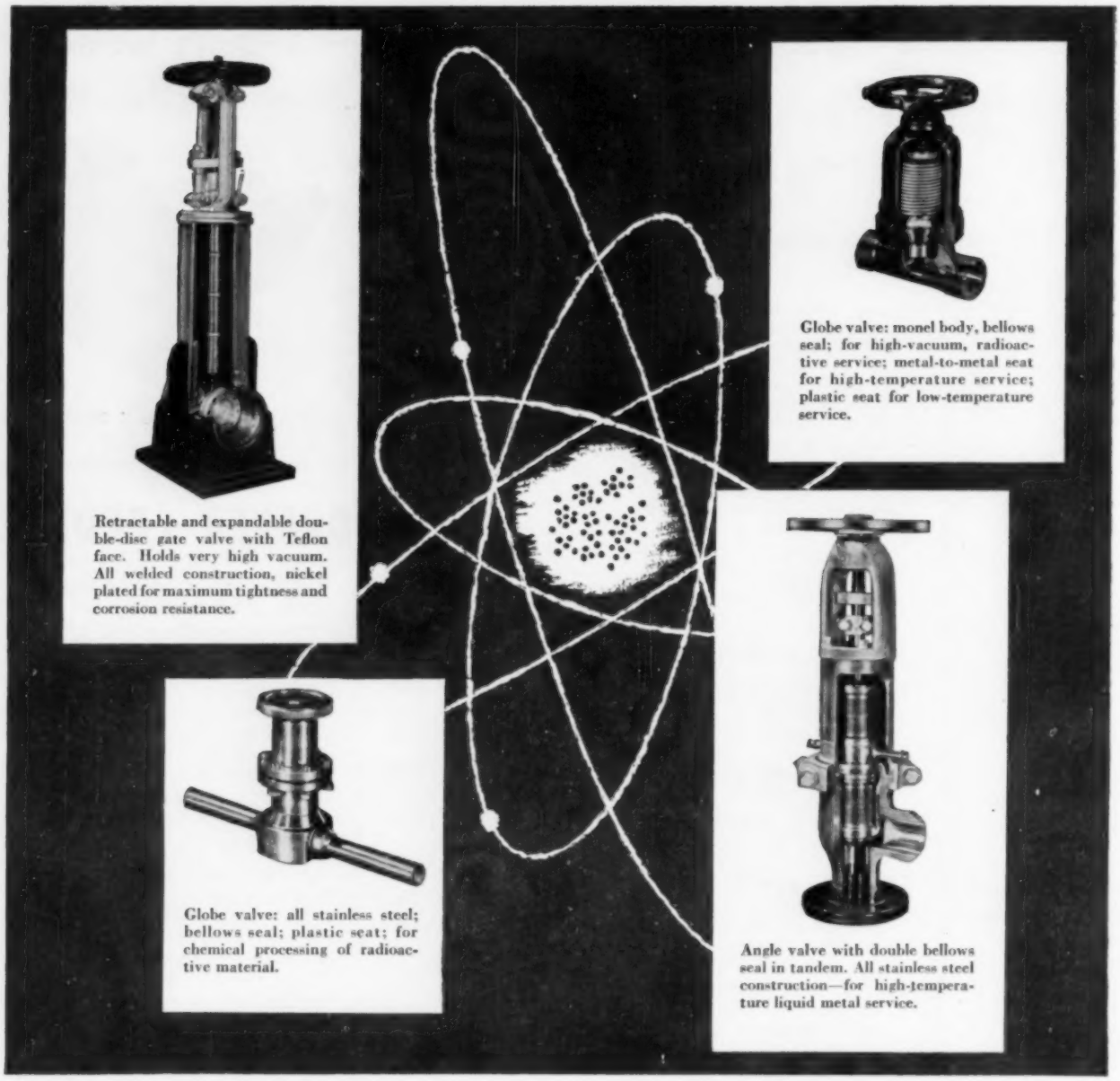
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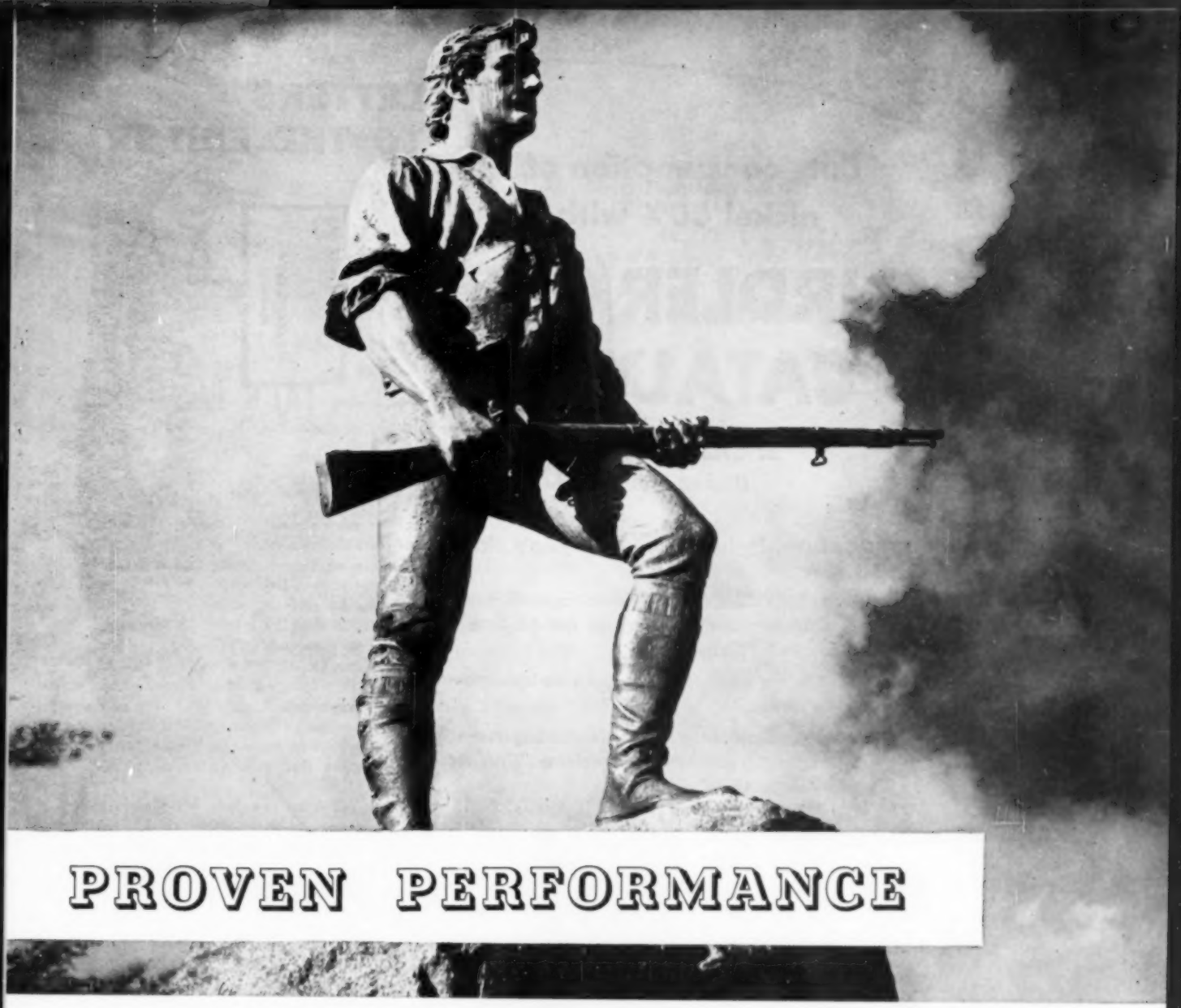

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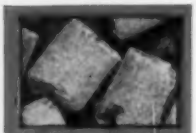

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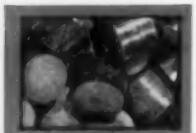

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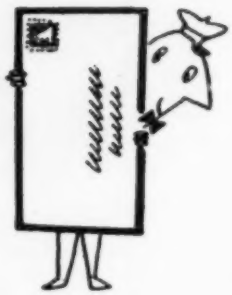
LETTERS TO THE EDITOR



Sulfur Recovery: A Misnomer

Ever since the sulfur shortage a couple of years ago the term "sulfur recovery" has been so bandied about that a person is almost trapped into reading an article on a somewhat different subject.

A trap appears in the title of Thompson's paper on Anaconda's Yerington sulfuric acid plant. [R. B. Thompson and Donald MacAskill, Dorr - Oliver Incorporated, C.E.P, August, 1955, page 369.] The title might have read, "Economical Manufacture of Sulfuric Acid from Low Grade Sulfur Ore" rather than economical "sulfur recovery."

Apparently the ruse was not the work of the authors for they consistently referred to sulfur dioxide and acid production.

SEYMOUR SCHWARTZ
New York, New York

My Kingdom for a Standard

In recently re-reading several articles from the "Proceedings of the Fifth National Conference on Standards" I was struck by one comment in your article "Frontiers for Standardization in the Chemical Process Industry." It was "The first job of these groups has been to develop nomenclature acceptable to purchaser, seller, and supplier of processing equipment."

It occurs to me that a step which should be taken should be adoption by the AIChE of "American Standard Abbreviations for Scientific and Engineering Terms."

I have been for some time responsible for the rather extensive development of engineering standards for my company. During the course of this work the disagreement between chemical engineers and all others as to such a simple thing as the use of periods with abbreviations and such terms as P.c.u. and Btu, has been a continual source of annoyance. It has been costly and time consuming and is distinctly at variance with the cardinal principle of "Standardization." . . .

(*Continued on page* 10)

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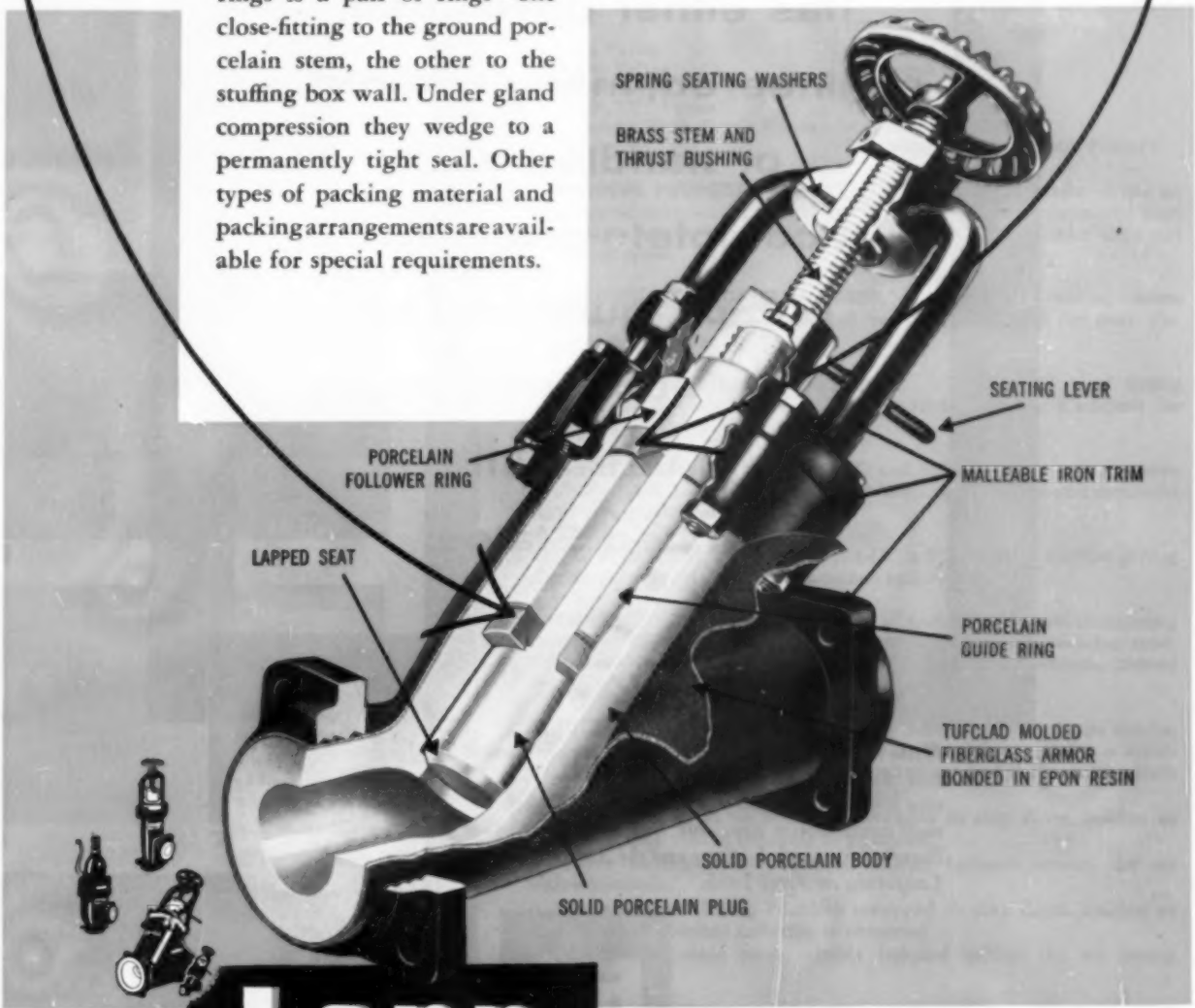

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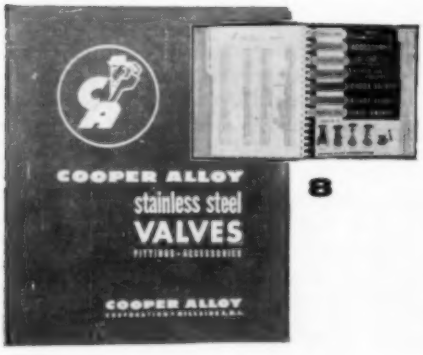

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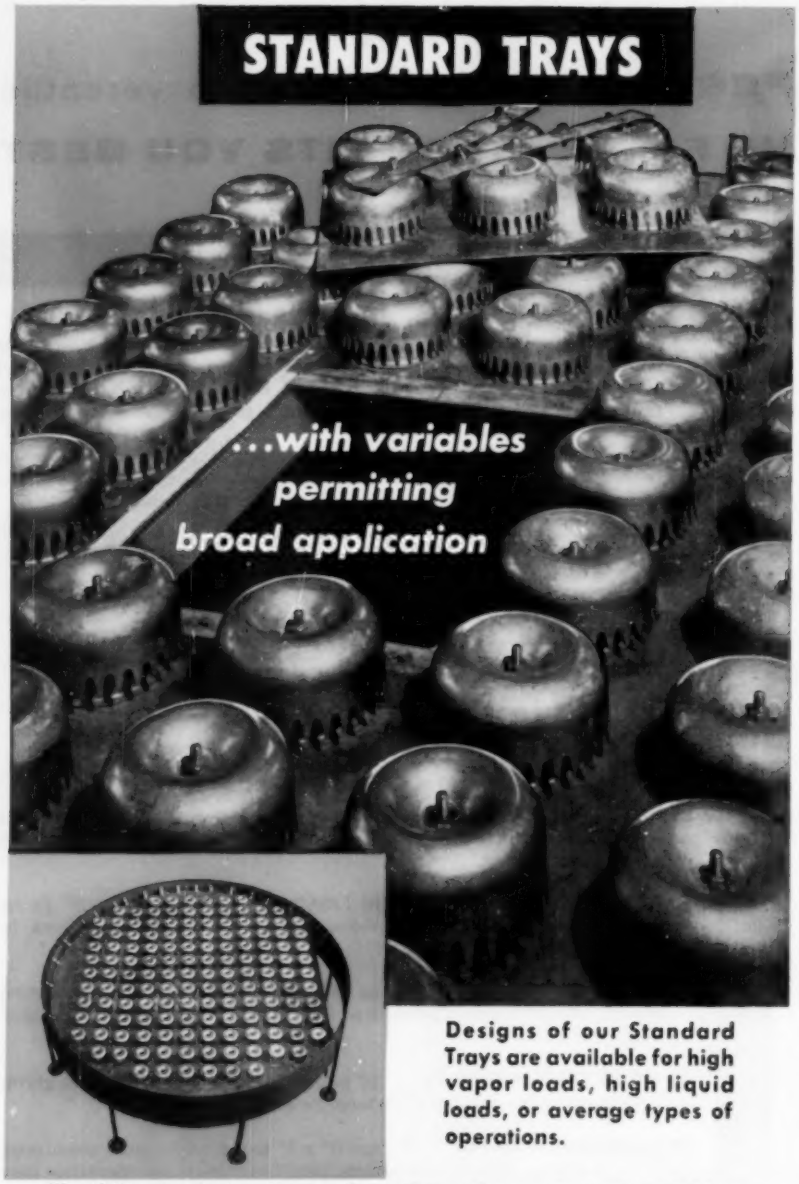

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LETTERS TO THE EDITOR

(*Continued from page 6*)

This subject has plagued me for some time and these comments to you constitute my first tangible effort to do anything about it. I would deeply appreciate your comments in this connection.

H. P. Dial

Montreal, Canada

∫ A.I.Ch.E. believes clarity and understanding are improved by use of standard English abbreviations for units and by use of periods. In American Standard Letter Symbols for Chemical Engineering ASA Z10.12, 1946, we state "The units, and the abbreviations for them, in the list are recommendations of the American Institute of Chemical Engineers and do not constitute a part of the present American Standard."

We stand almost alone as yet.

However, the ASA standard is not in itself consistent. ASA abbreviation for pound is lb; for square it is sq; in. is exception; for foot ft; for second sec. When these abbreviations are put together, foot pound second becomes fps instead of ft.lb.sec., and is confused with fps meaning feet per second. A.I.Ch.E. would write this ft./sec., which is understood immediately. Under ASA, pound per square inch becomes psi instead of lb./sq.in.

If any further proof is needed about the relative clarity of the systems—which is understood more quickly? ips (ASA abbreviation) where p might be pound or per or in./sec. (A.I.Ch.E. recommendation).

Periods are used after abbrevations because A.I.Ch.E. Committee on Symbols believes the extra bother pays off in easier understanding.

F. J. Van Antwerpen
Secretary, A.I.Ch.E.

NOTED AND QUOTED

Nuclear Fission as Heat—When?

Nuclear fuels—uranium and thorium—are basically cheap and plentiful and it seems clear that man in his never-ending search for heat and power will utilize them. We might note that even common granite rock, which contains about 30 parts-per-million of uranium and thorium together, has a "fuel value" about eight times that of coal on the assumption that 10 per cent of the uranium and thorium can be recovered and fissioned—surely not an unreasonable

(*Continued on page 24*)

POWELL VALVES ... THE COMPLETE QUALITY LINE ... POWELL VALVES

Fig. 2309—Flush Bottom Tank Valve for 150 Pounds W. P. Disc Opens Into Tank.

FIG. 2342—Flanged End Bolted Cap Swing Check Valve. For 150 Pounds W.P.

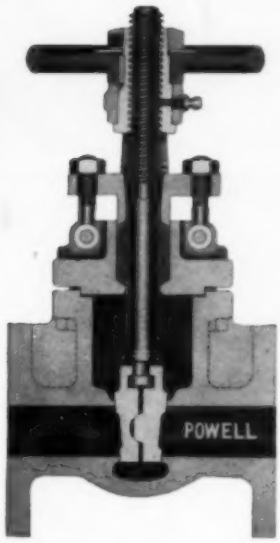

FIG. 2495 (Sectional)—Stainless Steel O. S. & Y. Gate Valve For 150 Pounds W. P. Double Wedge Disc Is Accurately Guided Into Seat.

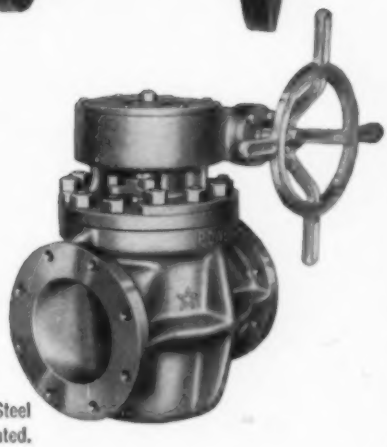

FIG. 3059-G—300-Pound Steel Lubricated Plug Valve. Gear Operated.

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Which of the many Celite advantages can you use to build product performance or cut production costs? A Johns-Manville Celite Engineer will gladly discuss your problem, without obligation. For his services or more information, simply write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Celite is Johns-Manville's registered Trade Mark for its diatomaceous silica products.

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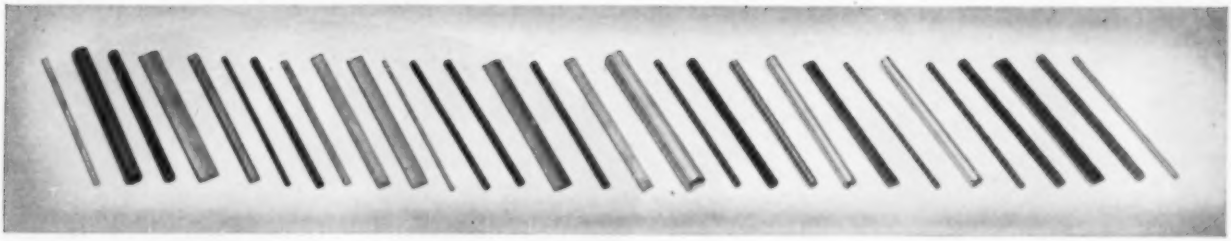
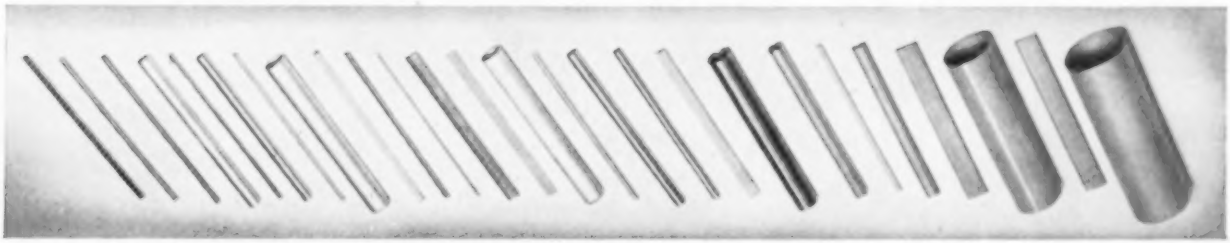


Tubing by Superior is in the nuclear power picture



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SHAPES AND LENGTHS. Squares and rectangles, ovals, ellipticals, triangulars, hexagons, step-tapered and telescoping shapes. Random tubing in almost all analyses can be produced to 30 ft. lengths. Certain specialties in coils up to 300 ft. Tiny short cuts, selected random, multiple, and straight random.

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QUALITY. We assure highest quality through such means as hydrostatic testing for pressure tubing, cyclographic inspection, tensile, Rockwell and salt spray inspection. Certified qualitative chemical analysis. We certify to ASTM, ASM and MIL specifications as standard practice and in many cases work to customer specifications. The personnel and facilities of our Quality Control Department are at your disposal for large production-run tubular components.

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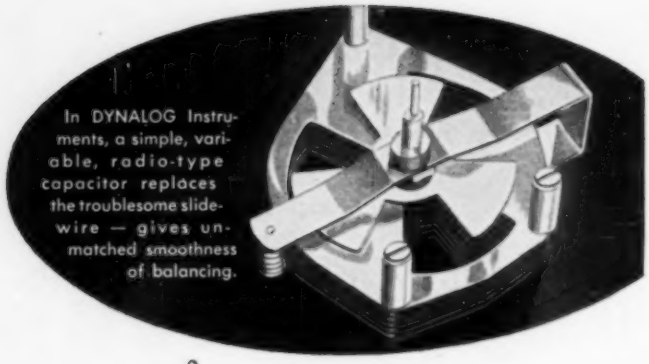
All analyses .010″ to ¼″ OD
Certain analyses in light walls up to 2½″ OD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Some impressions of the Geneva Conference, as noted by the Conference Secretary-General . . . himself a noted chemical engineer and nominee for 1956 President of A.I.Ch.E.

GENEVA CONFERENCE

Walter G. Whitman

We have just completed the International Conference on the Peaceful Use of Atomic Energy at United Nations Headquarters in Geneva.

The Conference was stimulating and exciting, especially to those of us who worked in its planning. It was originated last December when the General Assembly unanimously resolved that Mr. Hammarskjold should call a scientific conference to exchange information on the peaceful uses of atomic energy. I myself became involved when he appointed me as Conference Secretary-General.

Seventy-three Nations

Seventy-three nations accepted Mr. Hammarskjold's invitation to participate, over 1000 papers were contributed and will be published, together with the discussions generated by oral presentation of over 450 topics. Fourteen hundred delegates came to Geneva, and nearly 1400 observers, not included in national delegations but granted observers cards because of their competence and interest in the subject. These observers came from academic institutions, industry and business all over the world.

It was a friendly and human conference. Men of science from all over the world enjoyed the opportunity to mingle, to tell of their work, to discuss the findings and thinking of their fellows.

In the planning stages we went into every aspect of the Conference which we could imagine, and we argued vigorously and freely. To me—and to my twenty associates—the most surprising feature was that the arguments were not between, say, U. S. and Russian nationals, but between the physicists and the chemists, the biologists and the metallurgists, the chemical engineers and the mechanical engineers.

We all felt far more optimistic about the ultimate success of the Conference when we realized that cooperation and unity of purpose had been so quickly achieved in the planning group. It boded well, for the Conference as a whole and proved just that.

Profitable Exchange

You have heard much about the physicists who are unlocking the secrets of the atom, peering more deeply into its nature. The meetings of the physicists were one of the most important elements of the Conference. Much of their work is vital to the continuing work of the engineer. A single example will illustrate.

Knowledge of the cross-sections of the fissionable isotopes Uranium 233, Uranium 235, and Plutonium 239 is most essential in the design of reactors. Information on these cross-sections was formerly classified but became available at the Conference. Now an informal group of American, British, French and Russian scientists has prepared a set of values representing the best average of data from all countries. This will be a great boon to the engineer-designer.

But let me mention some of the other professional groups. The geologists told of where one may expect to find uranium and thorium, and of the best methods for searching them out. The engineers described how we have learned to handle hot metals like sodium. The metallurgists described newly developed processes for making fuel elements which can stand atomic bombardment. The agriculturists told of better strains of grains, and the geneticists warned us soberly against careless use of atomic energy which could hazard the future. The health physicists described the safety precautions which make work safer in atomic energy plants than in the average industrial operation. The engineer-designers outlined their constant striving for the dual goals of economical design and operation together with safety for workers and for the general community. It is clear that the peaceful applications of atomic energy can and will be developed under adequate safeguards for human health and the future of the race.

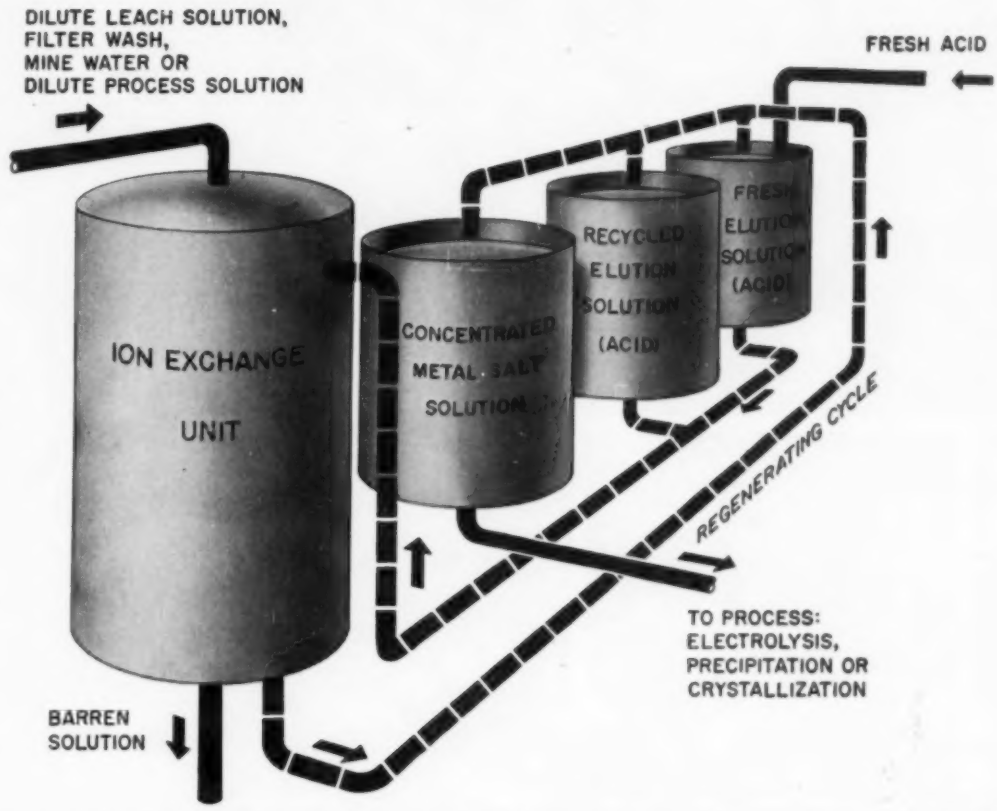
Much To Do

The United Nations staff still has a tremendous task to edit and publish in four languages the many papers and discussions of the scientists. These volumes will be rich sources of information to younger men in engineering and science who will be responsible for bringing the prospects of Geneva into full realization.

In closing let me venture into prophecy. We know that atomic power can annihilate us. But we are learning that it can also free us from many of the restrictions which have made the good life impractical for much of the world. This Conference has opened our eyes to the prospects of benefit to man. It has demonstrated that the nations are eager to co-operate in realizing those benefits and it has shown that their co-operation, through the United Nations, holds bright promise for the future. In the hands of the engineer, atomic energy can lead us to a new era of peace and plenty for all.

Condensed from talk delivered over CBS.

METAL CONCENTRATION BY ION EXCHANGE



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Ion Exchange gives Better Yields

• Ion exchange increases yields, simplifies flow sheets and cuts labor, supervision and chemical costs when used with other hydrometallurgical processes such as Leaching, Clarification, Filtration, Purification, Precipitation and Electrolysis.

The simplified flow diagram shown above illustrates the main principles of ion exchange in concentrating metals from leach liquors, filter washes, other dilute process solutions or mine waters:

As the feed solution or mine water passes through the ion exchange unit, the metal values are concentrated on the ion exchange resin, generally in preference to other ions present, leaving the solution or mine water metal-free. When the metal-attracting property of the resin is exhausted, an appropriate elution solution, for example an acid, is passed through the resin to pick up the metal. In most cases, the elution solution also acts as regenerant to restore the metal-attracting capacity of the resin . . . as shown on the diagram. Recycling the elution solution provides high concentrations . . . often several thousand times as concentrated as the original feed solution.

Ion Exchange methods apply to these metals:

Base Metals	Minor Metals	Precious Metals
Copper	Cobalt	Gold
Zinc	Tungsten	Silver
Lead	Molybdenum	Platinum
Tin	Vanadium	
Aluminum	**Decorative Metals**	**Rare Earths**
	Nickel	Lanthanide Group
	Chromium	Actinide Group
		Uranium

The Permutit Company not only designs and builds complete ion exchange systems, but also manufactures ion exchange resins and zeolites for all industrial applications. For information, write: The Permutit Company, Dept. CEP-10, 330 West 42nd St., New York 36, N. Y.

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COOLING and
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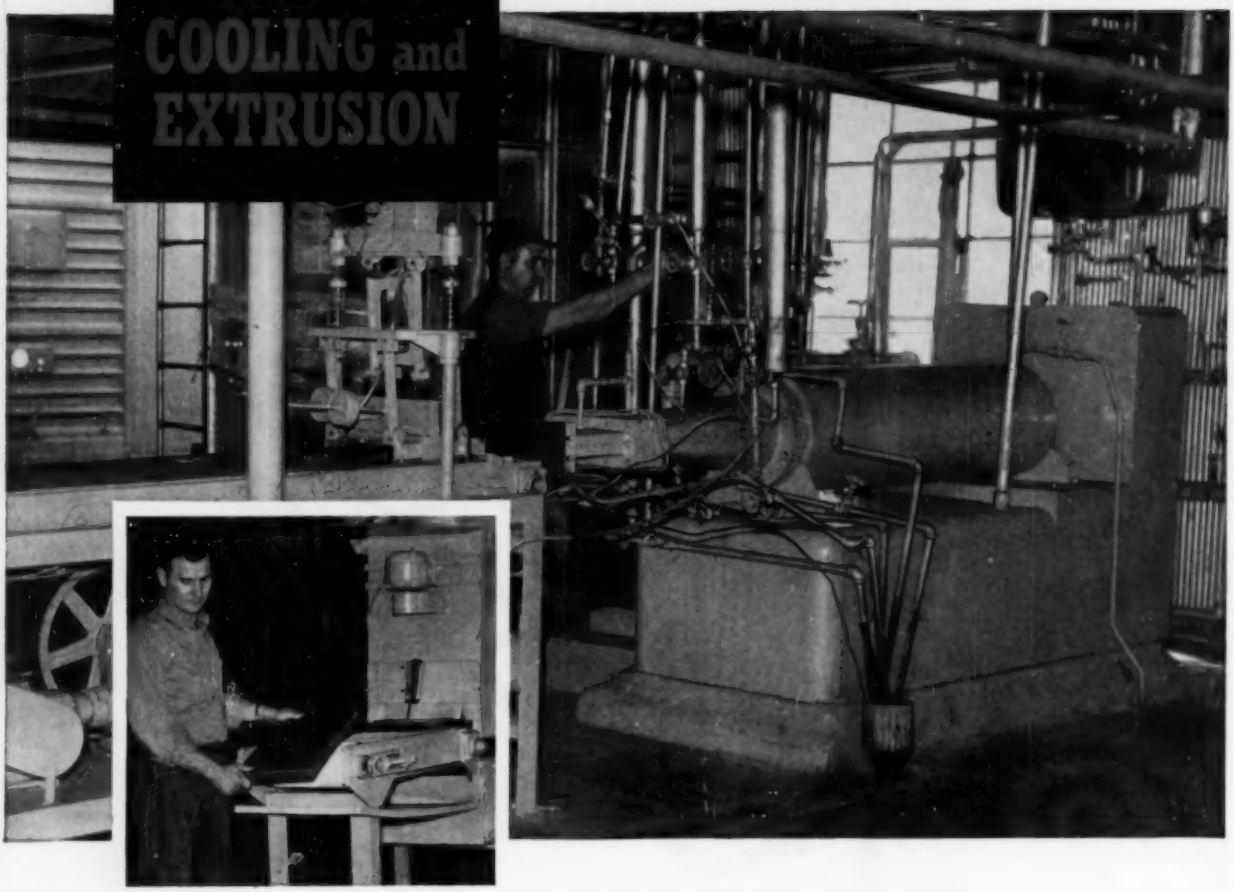

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WARWICK WAX COMPANY, INC., subsidiary of Sun Chemical Corporation reports the following benefits from modernization of wax-cooling with VOTATOR* Heat Transfer Apparatus (compared to former pan-cooling method):

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Operation is clean.

The VOTATOR Wax-Cooling Apparatus at Warwick cools the product from 220°F to 150°F and extrudes it into uniform 10-lb. slabs. Output is 3000 lbs. per hour.

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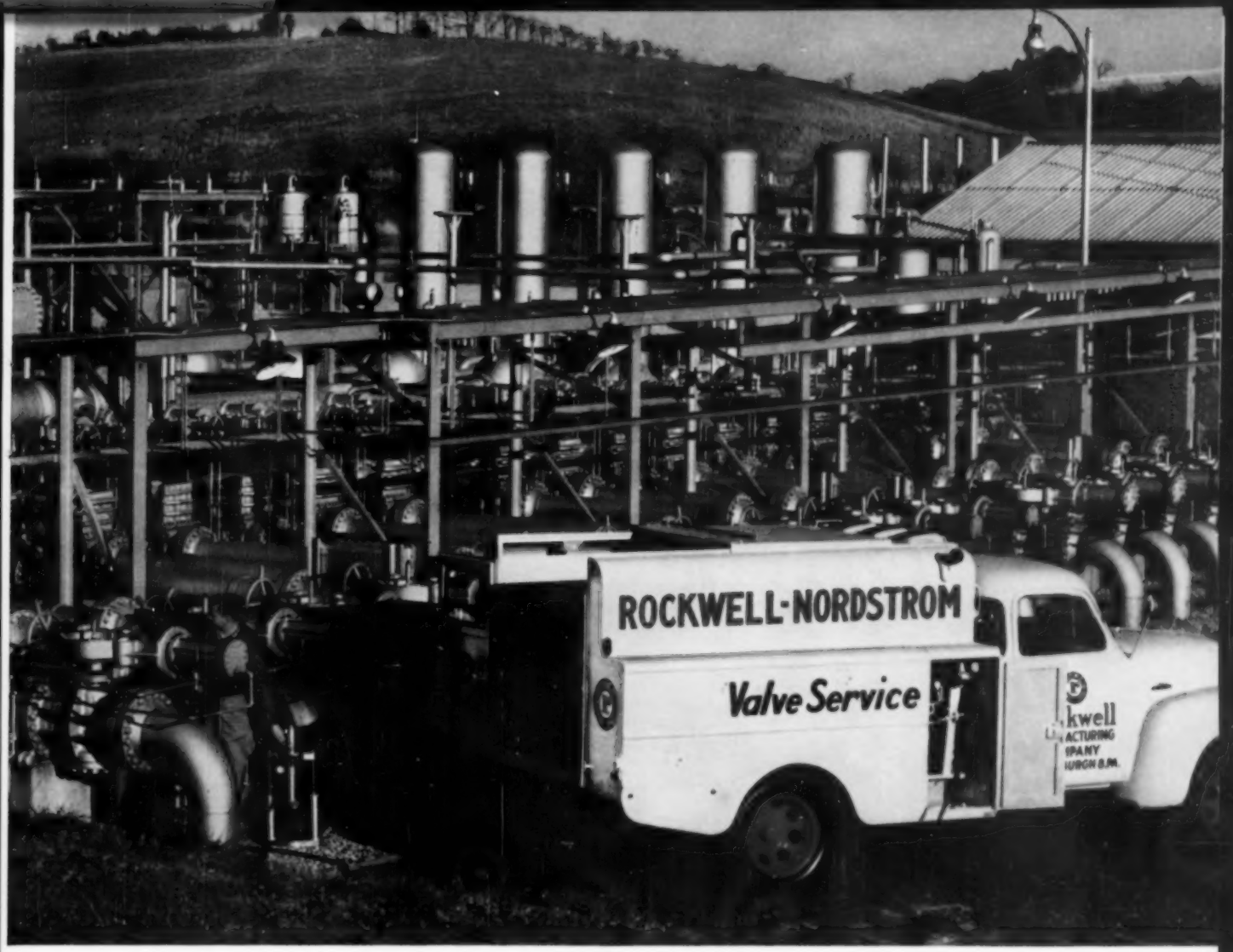


Investment in Economy

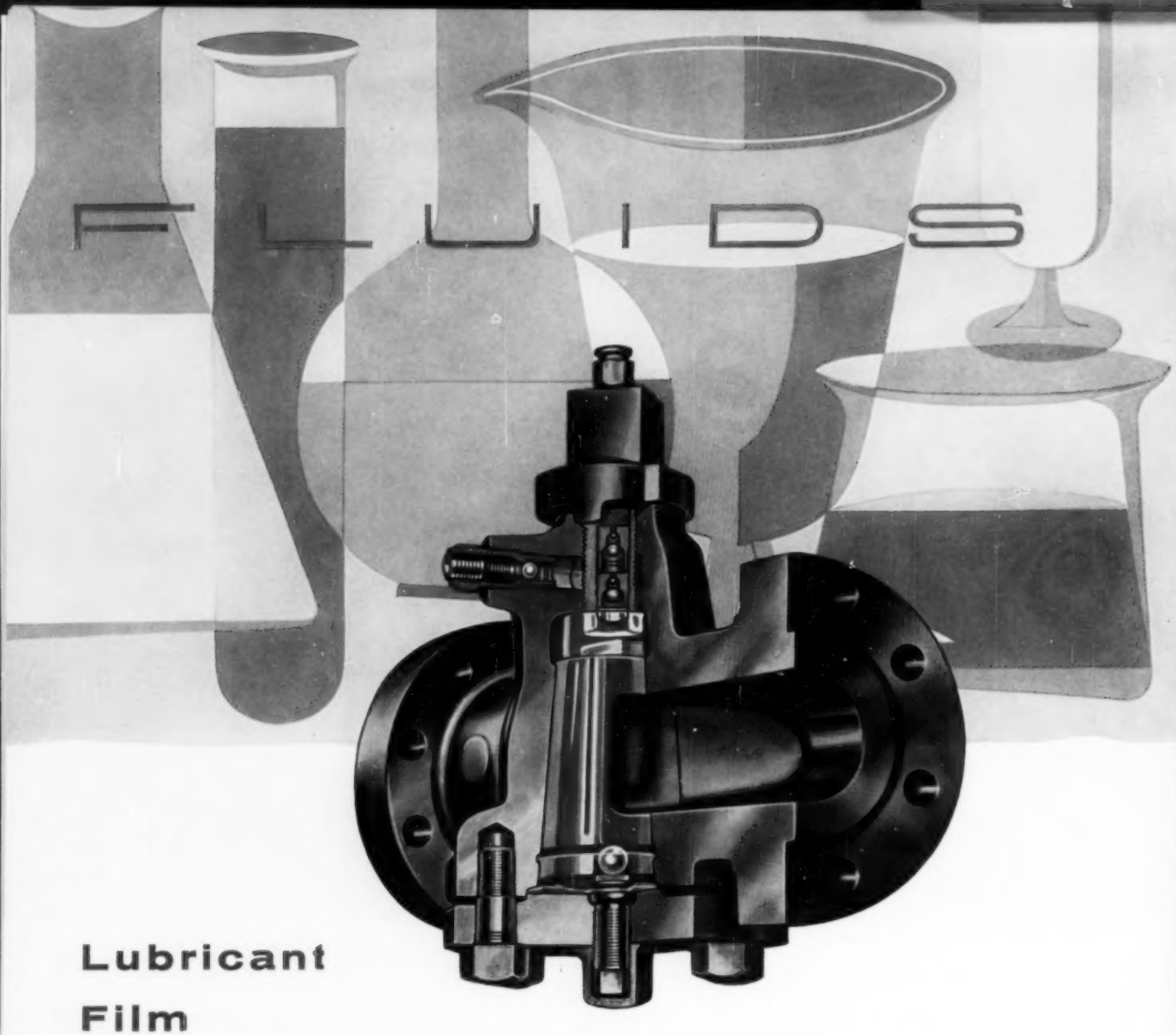
For forty years Rockwell-Nordstrom, the *original* lubricated plug valve, has built a reputation for valve economy. This year, Rockwell-Nordstrom users have even greater opportunities for valve economies through Rockwell's new mobile maintenance service, which is being made available on a contract basis.

Using the most up-to-date lubrication equipment on special Valve Lubrication Trucks, trained personnel will service all your Rockwell-Nordstrom valves on a schedule adapted to your individual requirements. These specialists will advise you on the correct Rockwell-Nordstrom lubricant for each of your services, and instruct your men on proper valve care that will allow further savings through greater efficiency and longer life.

Like Rockwell-Nordstrom valves themselves, this new Rockwell Contracted Maintenance Program has a single purpose: to give you the best valve service you've ever had, at the lowest cost per year. For complete information, write: Rockwell Manufacturing Company, Pittsburgh 8, Pa.

ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF



Lubricant Film Stops Metal-Hungry Fluids

Corrosive and erosive liquids are the nemesis of ordinary valves. But the thin, tough film of pressurized lubricant in Rockwell-Nordstrom valves forms an impregnable armor plating against them. And lubricant in the Sealdport* grooving provides a pressure seal that is dependably leak proof.

On liquid lines—or on any service—Rockwell-Nordstrom valves and lubricants will do a better job, longer, for less money. For complete information related to your valve problems, write: Rockwell Manufacturing Company, Pittsburgh 8, Pa.

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ROCKWELL-Nordstrom VALVES

LUBRICANT SEALED FOR POSITIVE SHUT-OFF

Advances in Applied Radiation

DEVELOPMENTS in the FIELD OF APPLIED RADIATION ENERGY, its APPLICATIONS and the APPARATUS USED TO PRODUCE IT

Bring your questions about radiation-energy applications to Booth 319—International Atomic Exposition Cleveland—December 10-16

Gulf Oil to Install Powerful Atom Smasher

Gulf Oil Corporation has announced plans for a nuclear science laboratory to be located at the company's research center in Harmarville, Pennsylvania. Principal unit in the laboratory will be a giant three-million-volt atom smasher which is being built by High Voltage Engineering Corporation, Cambridge, Massachusetts. This Van de Graaff Particle Accelerator, capable of producing virtually all the fundamental forms of radiation in powerful streams of electrons, x-rays, positive ions, or neutrons, will be installed approximately September 1, 1956.

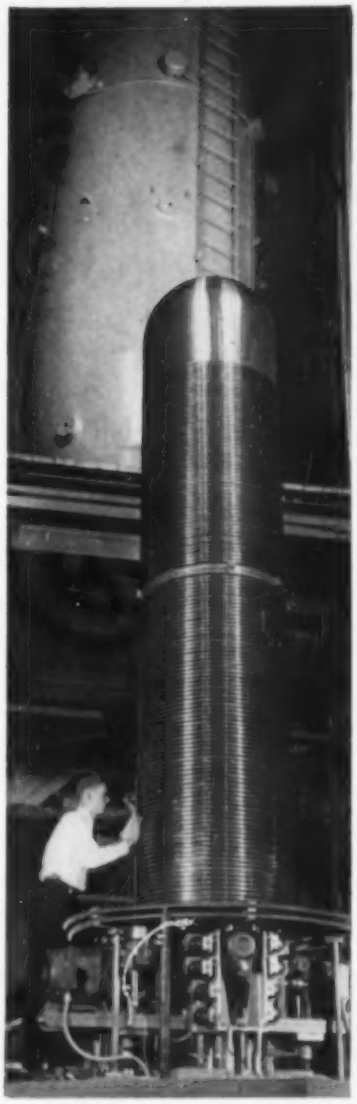
Gulf scientists will use the accelerator to study the effects of radiation on a wide range of petroleum and petrochemical processes, as well as for improved analytical techniques and the development of new catalytic agents — exploring every possible application of nuclear energy in the manufacture of petroleum and petrochemical products. Dr. Blaine B. Wescott, Gulf Vice-President in Charge of Research, expressed the hope that the new accelerator will solve many mysteries of petroleum refining and production still confronting scientists.

"We intend," Dr. Wescott pointed out, "to find out if radiation can be used to improve performance characteristics of petroleum products. Today we rely largely on heat to change or rearrange the molecular structure of crude oil in order that we may produce our petroleum products. Now we need to find out if, through nuclear energy, important improvements can be made in conventional refining and petrochemical processes. If this should prove feasible, it could lead to the development of totally new and different products as well as to more efficient refining operations whereby we can achieve absolute maximum usage from a barrel of crude."

Radiation-Sterilized Plastic Tubing Introduced

The first electron-sterilized plastic tubing available commercially is now being marketed by the Clay-Adams Company, Inc., New York manufacturer of medical and surgical equipment and supplies. The new product is marketed under the Clay-Adams registered trade name of "Intramedic" Polyethylene Tubing. Available in convenient lengths, the tubing is packaged in sterile, sealed, plastic envelopes. The whole package is irradiated in one operation by passing it through a beam of electrons emitted by HIGH VOLTAGE's 2-million-electron-volt Van de Graaff accelerator. Complete sterility within the envelope is achieved within a few seconds. HIGH VOLTAGE performed the experimental testing irradiations for Clay-Adams in its 2-million-volt radiation facility at its plant in Cambridge. The sterile tubing is available in diameters of from .038″ to .075″.

The irradiation of this plastic tubing by HIGH VOLTAGE further establishes that complete sterilization can be accomplished economically using a Van de Graaff as a radiation source.



Six-MeV Accelerator for France

The French Ministry of Education has ordered a six-million-volt Van de Graaff positive ion accelerator from HIGH VOLTAGE. Scheduled for installation in 1957, at the Institut de Recherche Nucléaires in Strasbourg, the accelerator will be used under the direction of Professor S. Gorodetsky to study the excited levels of nuclei.

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SPECIAL FEATURES OF BETHLEHEM PAN DRYERS

- scraping at wall and bottom if required with no galling
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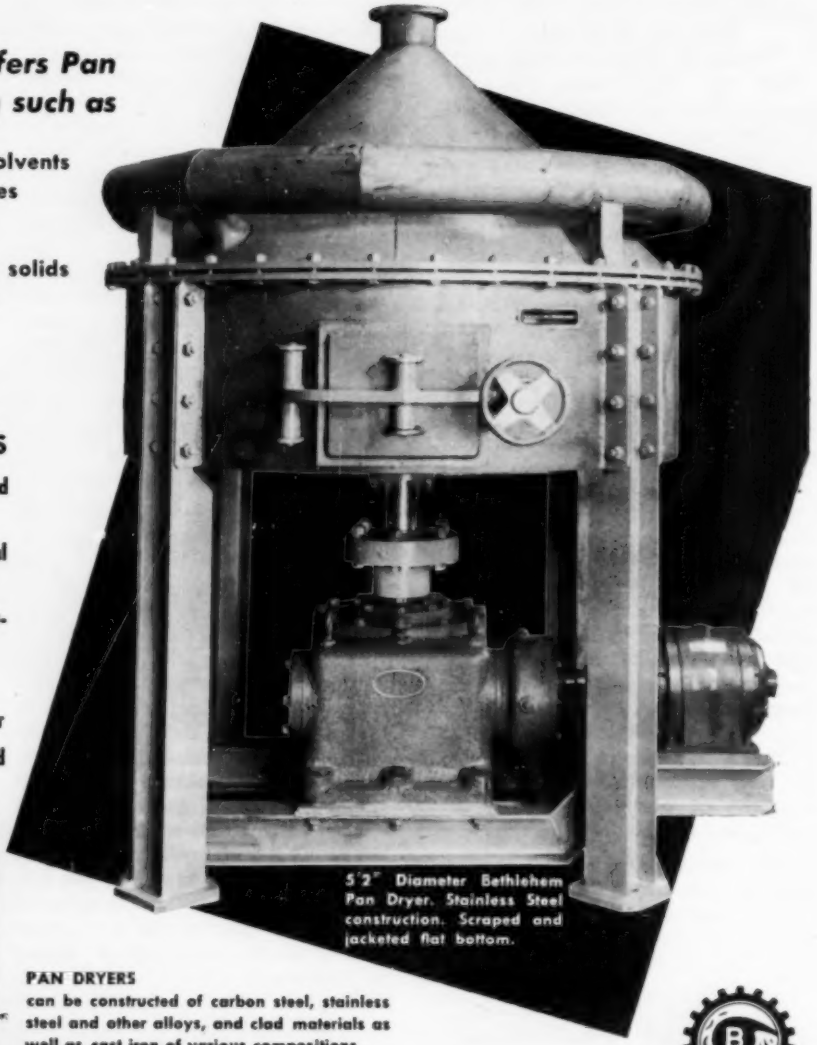
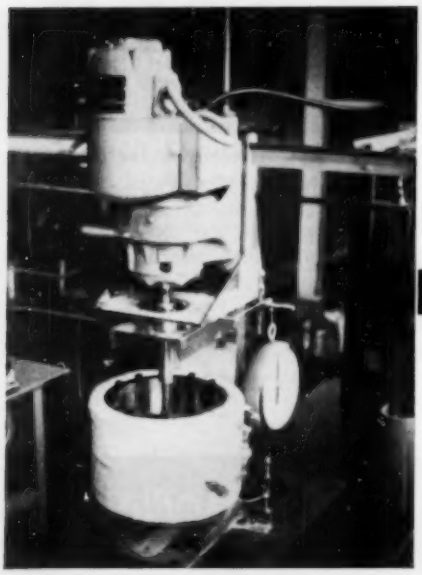
- intense agitation to break up and circulate material
- quick-opening discharge door
- rapid self-discharging action of agitator
- agitator blades designed and constructed to resist abrasion and wear



5'2" Diameter Bethlehem Pan Dryer. Stainless Steel construction. Scraped and jacketed flat bottom.

PAN DRYERS
can be constructed of carbon steel, stainless steel and other alloys, and clad materials as well as cast iron of various compositions.



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BETHLEHEM can help solve your problems for processing and handling sludge, pastes and other high-consistency materials. We offer—background with case histories—a variety of successful designs—research experience—laboratory test facilities.

Test data will uncover better and cheaper ways to handle or process your troublesome and high consistency materials. Write us today.

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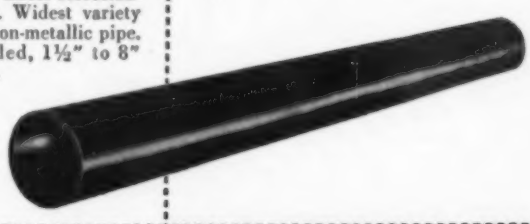
Ace hard rubber . . . now more than a century old . . . long the finest corrosion-resistant pipe available. Widest variety of fittings of any rigid non-metallic pipe. Sizes ¼" to 8" threaded, 1½" to 8" flanged. *Bulletin CE-51.*



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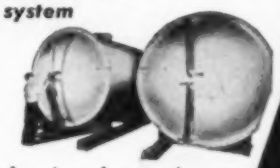
Rubber-lined by ACE 2-layer system



Economical, universal protection against all alkalis, metallic salts, practically all inorganic acids, hydrochloric acid any strength, sulphuric to 50%, nitric to 20%, phosphoric to 75%. Good to 160 deg. F. . . . sometimes higher. Soft rubber interlayer aids shock resistance.

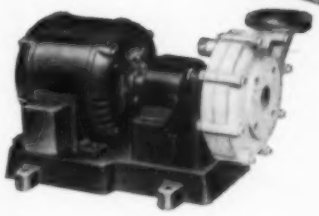
ACE chemical equipment

"more resistant to more corrosives"

Complete line of rubber and plastic processing equipment . . . eight basic materials for pipe and fittings, valves, pumps, tanks, molded parts, utensils, etc.

RIGID VINYL . . . STRONG, AGE-PROOF

Ace Riviclor is a new rigid threaded plastic pipe with good aging and high impact strength. Not affected by most inorganic acids and alkalis, also excellent for many organics. Sizes ½" to 4". *Ask for Bulletin CE-56.*



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Non-metallic Acid Pump

On job after job, this 80-gpm. centrifugal pump has earned highest praise. Hard rubber casing and impeller, Hastelloy C shaft. Handles nearly all corrosives. Mechanically simple, trouble-free. *Bulletin CE-55.* Larger Ace pumps available.

1001 USES *for ACE-FLEX Tubing*

Excellent chemical-resistant, all-purpose flexible plastic tubing. Sparkling clear, easy to clean, odorless, non-toxic, can be steam-sterilized. ⅛" to 1" ID. *Bul. 66.*

NEED SPECIAL FITTINGS, COVERS, TANKS, PARTS?

If you want life-time corrosion protection for special parts needed in quantity . . . we may save for you by molding them of Ace hard rubber or plastics to your most exacting requirements. Our facilities among world's largest. Ask for recommendations.

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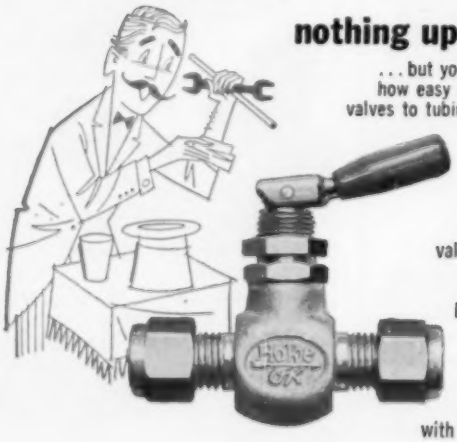
Hoke reports on fluid control!

we're giving you the needle

. . . to help you control small flow rates easily and accurately. The needle point in a Hoke Metering Valve is just 8° wide and it takes 20 turns of the handle to move the point ⅜ of an inch, the effective throttling length. In addition to this precise control, the Metering Valve has an O-ring stem seal (. . . so tight it'll pass a Helium Leak Test) and is available for instrument panel mounting.

Interested? . . . write for catalog and data sheets.



nothing up our sleeve

. . . but you'll be amazed to see how easy it is to connect Hoke valves to tubing the Swagelok way. No swaging, no sweat, no swearing . . . in fact, it's no trick at all to achieve a permanent valve-to-tube connection with a turn and a quarter of a wrench. Hoke makes precision needle valves, on-off toggle valves, check valves — in brass and stainless — equipped with Swagelok tube ends. Ask for Bulletin SV854.

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HOKE INCORPORATED

Fluid Control Specialists

143 S. DEAN STREET, ENGLEWOOD, N. J.

NOTED AND QUOTED

(*Continued from page* 10)

goal. However, for a very considerable time we should have much better nuclear fuel sources than granite.

W. Kenneth Davis
at seventeenth annual meeting,
American Power Conference
Chicago, Illinois.

Potentialities of the Atom

. . . the essential ingredient to atomic survival is a broad base of informed and interested civilians. It is the only way in which we can cope with the immoral fatalism that considers war "inevitable"—with the folly that professes unconcern over man's darkest threat. . . .

Perhaps the secrecy with which we have guarded certain especially sensitive areas of atomic information contributes to this apathy. But the extent of this secrecy is greatly exaggerated; it is more an alibi for than an explanation of our abandonment of the normal functioning of public opinion. . . .

It seems clear to me that, "realistically" and humanely, we should use the atom to help eliminate want where it already exists and to forestall want where it threatens. By developing nuclear power, we can simultaneously enrich ourselves and the world, materially and spiritually. . . .

"God *Meant* Us to Find the Atom"
Thomas E. Murray
Better Homes & Gardens

MARGINAL NOTES

Liquid Metals Handbook, 3 ed. (Sodium-NaK Supplement). Sponsored by The Atomic Energy Commission and The Bureau of Ships, U. S. Navy. Carey B. Jackson, editor-in-chief. Government Printing Office, Washington 25, D. C. 445 pages, paper covers, $2.00.

Reviewed by Charles F. Bonilla, Professor, Chemical Engineering, Columbia University, New York.

This volume is the last project initiated by the Liquid Metals Committee before its activities were transferred to the A.I.Ch.E. It is a worthy successor to the earlier editions, and should be in the library of every engineer in the nuclear field or otherwise concerned with liquid metals. It is completely up to date throughout, containing much un-

(*Continued on page* 32)

DESIGNING ENGINEERS AND CONSTRUCTORS

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FOR THE PETROLEUM AND CHEMICAL INDUSTRIES

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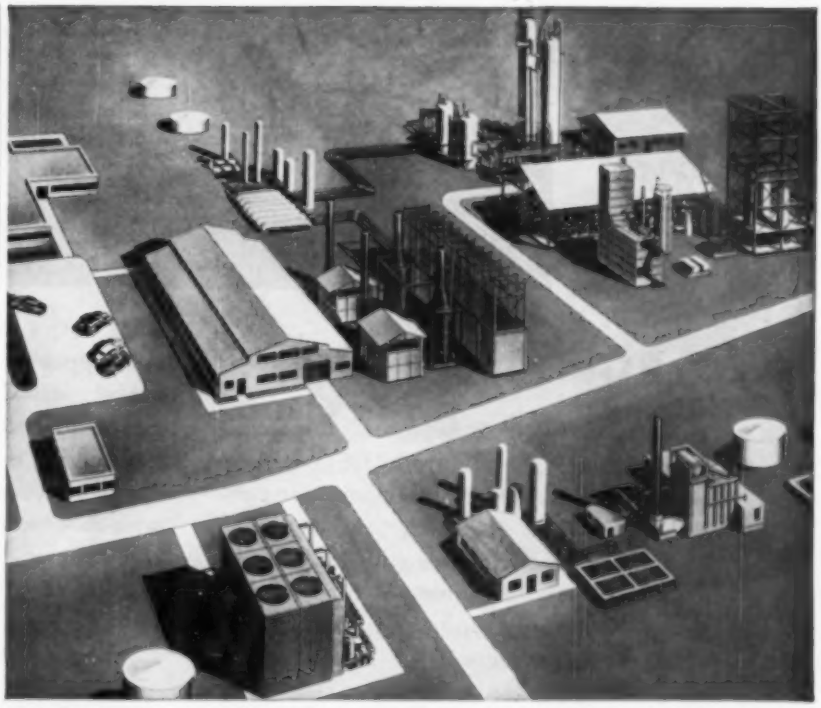
First Complete Ammonia Products Plant Planned For Puerto Rico

Lummus designed unit and will do construction

Construction will begin shortly on a new anhydrous ammonia, sulfuric acid and ammonium sulfate plant at Guanica, Puerto Rico for Gonzalez Chemical Industries, Inc., San Juan. With the creation of this industry, the second largest new endeavor on the island, another milestone is passed in the Puerto Rican Government's industrialization program.

The plant will provide a dependable source of ammonia-nitrogen and related products for fertilizer and industry of the island. This is of particular importance in times of international emergency when shortages may seriously handicap growers of sugar cane, tobacco, coffee and other industrial chemical developments.

Forty-two thousand tons of anhydrous ammonia will be produced per year. Part will be sold as such, and the balance will be converted to aqueous ammonia, sulfuric acid, ammonium sulfate and possibly other materials for use by agriculture and industry.



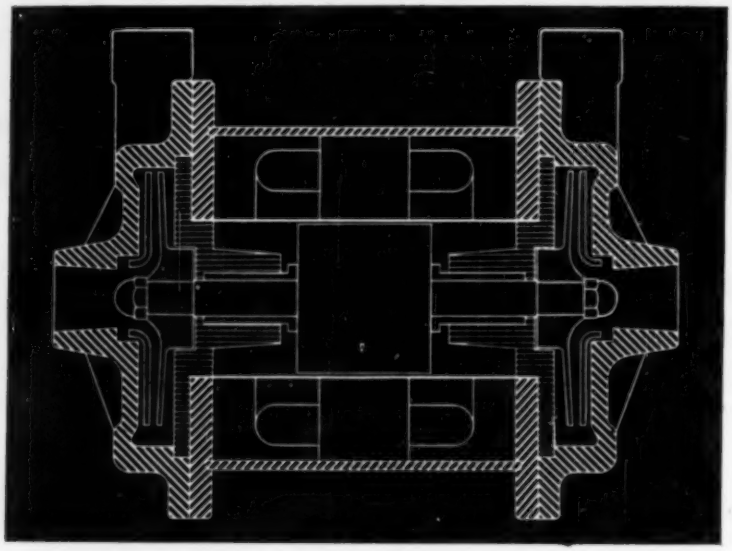
Artist's conception of complete ammonia products plant for Gonzalez Chemical Industries, Inc., Guanica, Puerto Rico.

This will make the fourth ammonia unit in two years for Lummus. It adds another to the 700-odd plants and installations completed by Lummus throughout the world. May our engineers serve you—at home or overseas?

The Lummus Company, 385 Madison Avenue, New York 17, N. Y. **Engineering & Sales Offices:** New York, Houston, Montreal, London, Paris, The Hague, Bombay. **Sales Offices:** Chicago, Caracas. **Heat Exchanger Plant:** Honesdale, Pa. **Fabricated Piping Plant:** East Chicago, Indiana.

New "DOUBLE-ENDED" Chempump

for high volume, high head leakproof pumping



TWO PUMPS IN ONE...

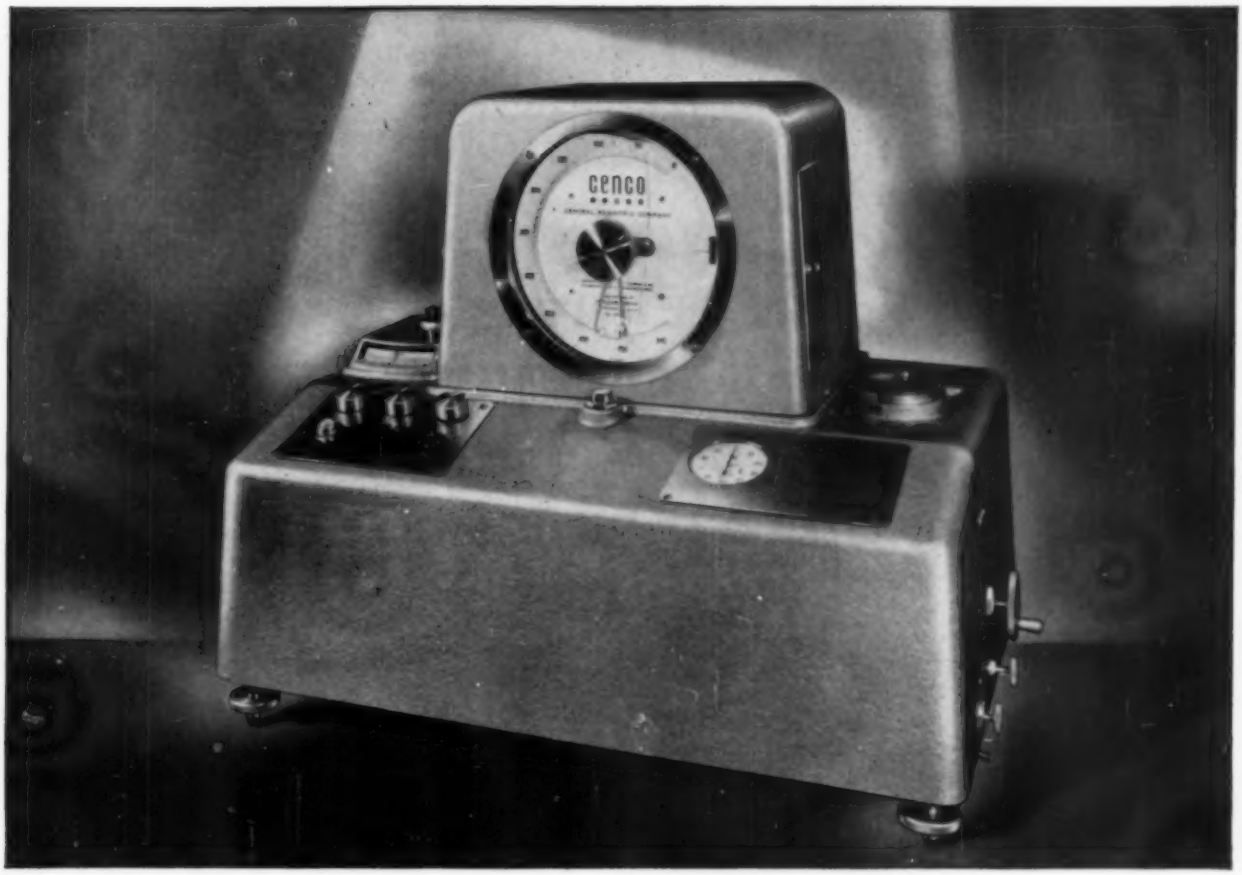
Balanced thrust at all deliveries is automatically assured in the new Model DE *Chempump* —first "canned" centrifugal pump for two-stage operation. Essentially two *leakproof* pumps in one, the double-ended *Chempump* is ideal for handling unusually high head or high volume applications, particularly where space is at a premium.

The new "2-in-1" *Chempump* can be manifolded so that the two volutes work in series or parallel. For high volume pumping, parallel manifolding and identical pumping ends are used. Thrust components are equal and opposite on either side and thereby cancel out. When supplied for series operation, automatic thrust balance, despite head differential, is maintained by design differences between the two pumping ends. As with all *Chempumps,* pumped fluid enters the rotor chamber of the Model DE to cool the bearings, rotor, and stator...and to lubricate the bearings. There are no seals, no stuffing boxes. *Chempump can't leak!*

For complete details, write to Chempump Corporation, 1300 East Mermaid Lane, Philadelphia 18, Pa. *Engineering representatives in over 30 principal cities in the United States and Canada.*

SEE IT
at the *Chempump* exhibit, "25th Exposition of the Chemical Industries," Dec. 5-9, Convention Hall, Philadelphia, Booths 314 & 316.

Chempump — **first in the field . . . process proved**



For faster...more accurate measurement of percentage hydrogen in liquid hydrocarbons...

Cenco Beta Ray H/C Meter

This instrument utilizes the absorption of beta rays as a means of measuring the percentage of hydrogen, or the hydrogen-carbon ratio, in liquid hydrocarbons. It is a practical precision instrument designed for use in research as well as in product control and routine analysis. It is the fastest known means of obtaining this important information, doing the entire job in a matter of minutes instead of the hours required by combustion train methods.

The Cenco Beta Ray H/C Meter is accurate to within 0.02 weight percent hydrogen. Calibration is independent of pressure changes in ionization chambers since they share a common supply of gas. Temperature changes do not affect measurement since both specific gravity and beta absorption measurements are made automatically and at the same temperature. Adequate shielding makes the instrument safe from radiation hazards.

Our Bulletin No. 115 contains full details. Write for your copy today.

Manufactured and sold only by Central Scientific Company by arrangement with Standard Oil Company (Indiana).

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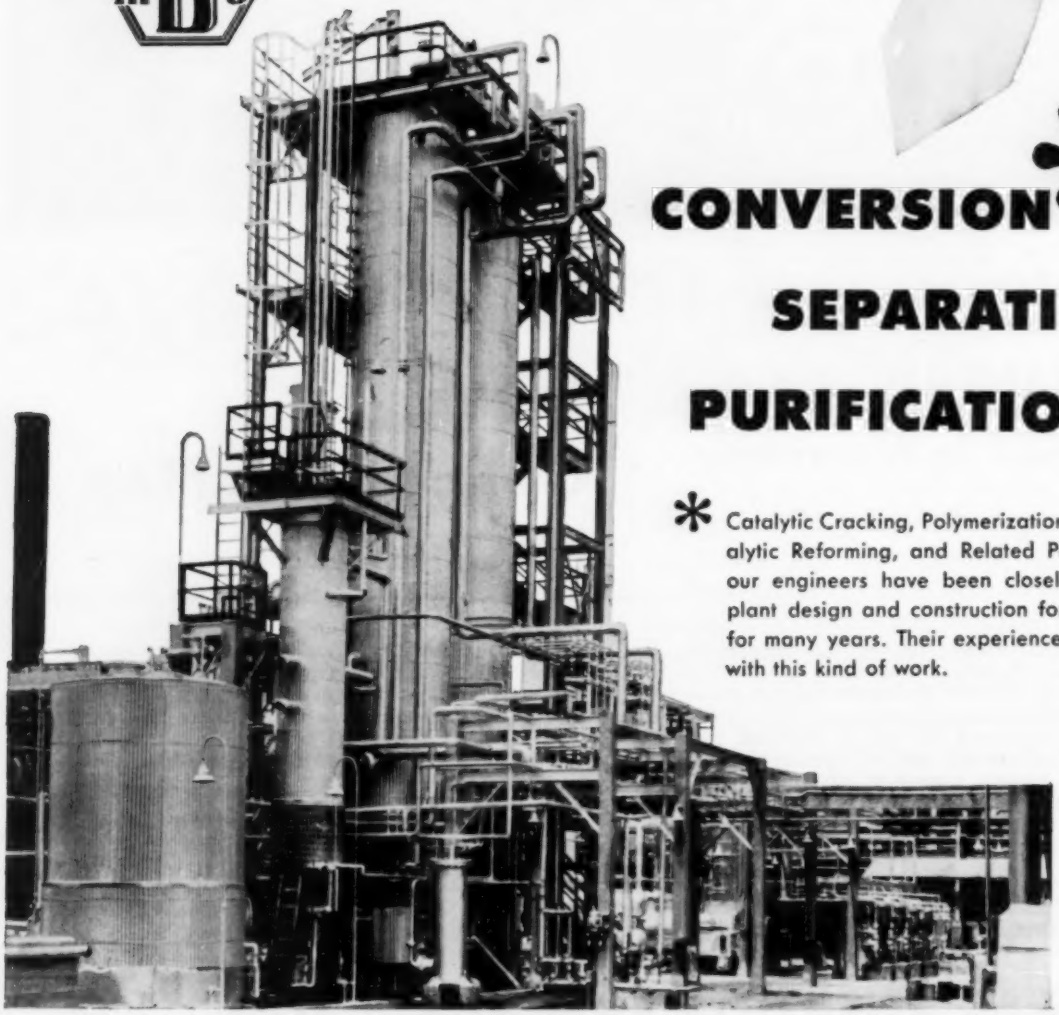

CONVERSION*

SEPARATION

PURIFICATION

* Catalytic Cracking, Polymerization, Alkylation, Catalytic Reforming, and Related Petrochemicals . . . our engineers have been closely identified with plant design and construction for such processing for many years. Their experience is tied in closely with this kind of work.

BADGER MANUFACTURING COMPANY

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Only Ingersoll-Rand Chemical Pumps offer you the exceptional

CORROSION RESISTANCE

of IRCAMET

This special alloy steel, developed for chemical pumps, easily handles a wide range of corrosive solutions ...from sulphuric acid to caustic soda!

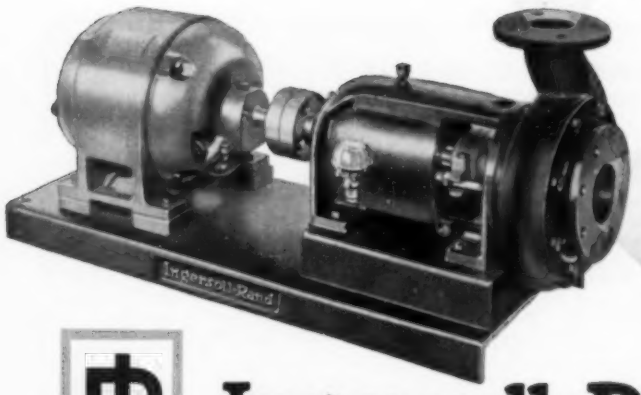
Na_2CO_3 NH_3 H_3PO_4 H_2SO_4 NaCl NaOH CH_3COOH

The ability of I-R chemical pumps to withstand such a wide range of strong corrosive solutions is the result of years of metallurgical research—both in the laboratory and in the field.

All parts of the pump that come in contact with the liquid are made of IRCAMET—a high nickel-chromium-molybdenum alloy steel, specially developed for chemical pump service.

The problem of *leakage*, too, has been successfully solved by a patented LEAKOLLECTOR stuffing box gland that completely encircles the shaft and stuffing box. In addition, all I-R chemical pumps can be supplied with a packless CAMERON SHAFT SEAL that requires practically no attention or maintenance.

These performance-proved I-R chemical pumps are available in sizes from ¼ to 125 hp, with capacities from 10 to 4000 gpm. For complete information, write for Bulletin No. 7095-A. Or if you have a pumping problem of any kind, just call your nearest Ingersoll-Rand representative. He will be glad to help you.



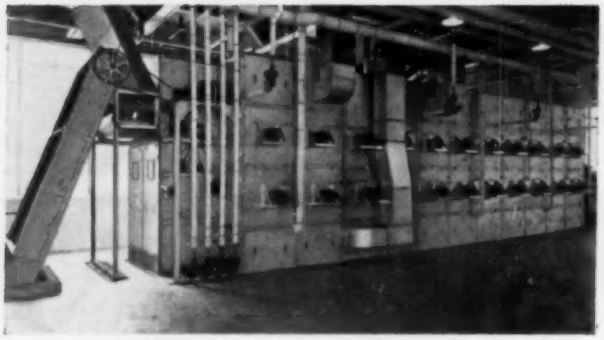
CH_3COOH NaOH NaCl NH_3 H_2SO_4 H_3BO_4 Na_2CO_3

Ingersoll-Rand

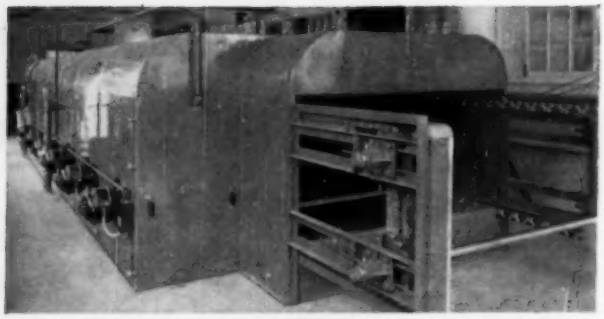
10-204

Cameron Pump Division
11 Broadway, New York 4, N. Y.

PUMPS • CONDENSERS • TURBO-BLOWERS • COMPRESSORS • AIR & ELECTRIC TOOLS • ROCK DRILLS



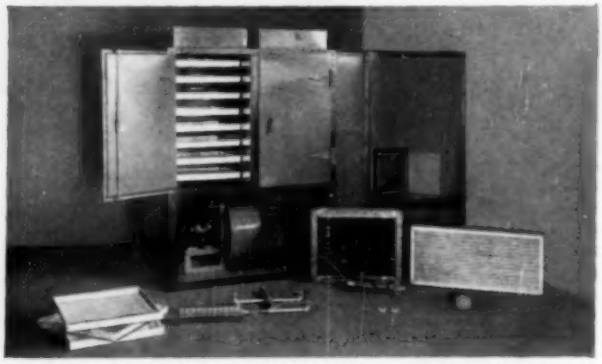
Reclaimed Rubber Dryer installation, showing fan placement. This dryer is an accepted standard in the rubber industry.



Skein Dryer installation in a textile mill. It meets modern demand for economy of operation, for production, and for protecting yarn quality, strength and fine desirable hand.

INDUSTRIAL DRYERS

by SARGENT



A SARGENT Tray Dryer and Air Washer installation in cottonseed oil processing plant. Shows trays, dirt eliminator, Sylphon Regulator and spray nozzles in foreground.

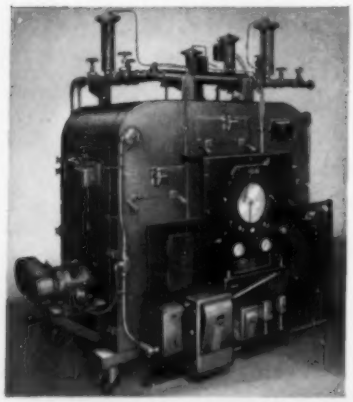
SARGENT Dryers are job-designed and job-guaranteed. They are the product of our experience gained through many years of designing and building specialized dryers for industry; and through years of trouble-shooting work for a wide variety of industries, in SARGENT'S Drying Research Laboratory.

Wherever a drying process occurs, SARGENT is highly qualified, and has complete facilities, for research, designing, engineering and for building, special drying equipment.

Our fully equipped Drying Research Laboratory is maintained at Graniteville, staffed by highly competent research and engineering personnel. Drying research facilities are available to clients at a nominal charge, to aid in solving the drying problems of almost any industry.

Here are Some of the Products of Industries We Serve:

Abrasives	Nuts and Nut Products
Animal Hair	Paints and Pigments
Building Materials	Paper and Paper Products
Explosives	Plastics
Feedstuffs	Rubber
Fertilizers	(reclaimed, synthetic, natural)
Fruits and Berries	Tobacco
Grains	(leaf, stem, filler)
Kaolin	Textiles
Leather and Hides	(fibre, yarn, cloth)
Inks and Pigments	Vegetables
Metal Parts	Waste Sludges



SARGENT'S PORTABLE LAB DRYER FOR RESEARCH LABORATORIES, PILOT PLANTS, UNIVERSITY LABS

Developed to reproduce every possible condition met in drying for the process industries. COMPLETELY SELF-CONTAINED, needs only service connections when delivered. MOBILE — may be moved to job in plant where needed. Perforated stainless trays (may be had also of wire cloth) are located for updraft, downdraft, cross-draft air circulation in dryer. COMPLETE temperature controls — recording charts, wet and dry bulb thermometers. RECORDS TEMPERATURE CHANGES THROUGHOUT BED OF MATERIAL BEING DRIED. Temperatures to 325° using steam heated air, or to 500° using electricity. WE BELIEVE THIS DRYER IS MORE VERSATILE AND HAS MORE POSITIVE CONTROLS than ever before offered to industry. Available on three plans — direct purchase, rental, or rental-purchase. Ask for Bulletin #204.

C. G. SARGENT'S SONS CORPORATION
Graniteville, SINCE 1852 Massachusetts

PHILADELPHIA 19 — F. E. Wasson, 519 Murdock Road
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ATLANTA, GA. — J. R. Angel, Mortgage Guarantee Building
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announcing

a new line of **small-size** **easy-to-read** gauges and receivers

NEW **REPUBLIC V5 GAUGES**

Individual, Independent Measuring Units for
DRAFT • PRESSURE AND VACUUM • DIFFERENTIAL PRESSURE • TEMPERATURE
High Accuracy Receivers for Pnuematic Transmitters and Electric Meters Measuring
FLOW • PRESSURE • CO_2 • DENSITY • LIQUID LEVEL • OTHER PROCESS VARIABLES

Important Features

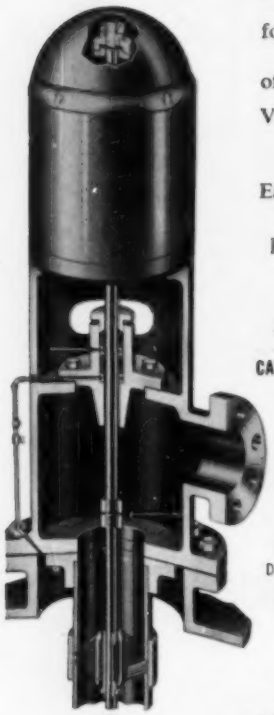
- FIVE INCH ILLUMINATED SCALES
- INDEPENDENT, INTERCHANGEABLE UNITS
- MULTIPLE OR INDIVIDUAL MOUNTING — from one to eight units to a single case
- EASILY MOUNTED—no panel drilling necessary in most cases
- SCALES EASILY CHANGED OR COLOR-CODED
- POINTER MOTION REVERSIBLE
- SIMPLIFIED CONNECTIONS AT BACK OF CASE
- REMOVAL FROM FRONT OR BACK

Now you don't have to sacrifice instrument performance and readability to size considerations. With Republic's new line of small-size V5 Gauges, you can save panel space, make more compact instrument groupings and *still* get the accuracy, sensitivity and readability you would expect from conventional sized instruments. Full sized diaphragms, bellows and helix units in V5 Gauges assure "big" gauge performance in an instrument that requires only one-fourth the panel space of conventional gauges. Five inch scales are almost flat and are indirectly illuminated as a standard feature for easy reading — even from a distance.

• ***Write for New V5 Bulletin*** ▶

REPUBLIC FLOW METERS CO.
2240 Diversey Pkwy., Chicago 47, Illinois

Verti-Line
CLOSE-COUPLED PUMPS
for every Industrial Vertical Pump Installation



The Verti-Line Close-Coupled Pump is not just another deepwell pump adapted to industrial service. It is designed and engineered for such jobs as booster service, fire protection, cooling, transfer and general service pumping of water and other fluids, corrosive or non-corrosive.

Verti-Line Pumps are made to the highest standards of quality in workmanship and materials to assure a *precision built* product. Each unit is thoroughly tested and rigidly inspected, insuring ease of field assembly and perfect performance—guaranteed to meet the most exacting specifications.

Whatever your vertical pump needs, investigate Verti-Line Pumps before you buy.

CAPACITIES FROM 20 GPM TO 30,000 GPM — HEADS TO 600 PSI

Heavy-Duty Fabricated Discharge Head With Solid Shaft Motor

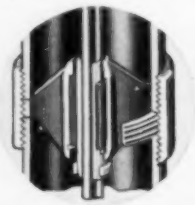
In-Line "T" Type Fabricated Discharge Head With Hollowshaft Motor

Standard Discharge Head With Combination Gear and Motor Drive

TYPICAL CONSTRUCTION FEATURES

(Open lineshaft type . . . Enclosed lineshaft also available)

The packing assembly is simple and effective. It is easily accessible and consists of a packing container, lantern ring, packing rings, pressure relief bushing, gland, fluid by-pass and lubrication fittings. Mechanical shaft seals also available.



Outstanding feature of bearing assembly is removable stainless steel shaft sleeve. This prevents shaft wear and bearing journal corrosion, and is easily replaced without special tools. You simply remove the old and slip on the new which is secured by a stainless steel collet.

Dual bowl bearings of rubber and bronze are supplied in most open and enclosed lineshaft pumps. Extra stability and resistance to abrasives mean longer life.

Send for your free copy of our new booklet, "Pumps for Sale." Ask for Bulletin C-105.

Verti-Line Pumps are the exclusive products of

LAYNE & BOWLER PUMP COMPANY

general offices and main plant

2943 VAIL AVENUE • LOS ANGELES 22, CALIFORNIA

MARGINAL NOTES

(*Continued from page 24*)

published or recently published material, and is as complete as could be expected in the pages allotted.

The handbook is organized as six chapters, each with its editor, containing in total thirty-one sections, each in general coauthored by two specialists from different laboratories. From experience with previous editions, it will soon be out of print due to heavy demand.

As indicated by the title, most of the chapters deal exclusively with sodium and sodium-potassium alloys, and to a lesser extent with potassium. These particularly include 48 pages on chemical and physical properties, 138 pages on purification and handling, 113 pages on instrumentation and equipment, and 30 pages on three large-test installations.

The 51 pages on heat transfer and insulation, 17 pages on flow characteristics, and 42 pages on thermal stress analysis and piping design are more generally applicable to all liquid metals and provide good current summaries on these topics.

The typography is good—the type is sharp, and only one misprint, one erroneous equation (in the middle equation of page 78, 1/43 should read 0.144), and one inverted illustration were noticed.

The volume fills a definite need in view of the increasing consideration of sodium and NaK at high temperature–low pressure heat transfer media.

Nuclear Reactors for Industry and Universities. Edited by E. H. Wakefield, Instruments Publishing Company, Pittsburgh 12, Pennsylvania (1954), 94 pages, $2.00.

Reviewed by Herbert S. Isbin, Department of Chemical Engineering, University of Minnesota, Minneapolis, Minnesota.

Timeliness becomes a forgotten issue for a book written in 1953, published in 1954, and reviewed in 1955. For this case, our nuclear reactor progress has proceeded at a much faster pace than our literary efforts. Events which have dulled the value of this book include the Atomic Energy Act of 1954 along with the current interpretations and procedures, and the variety of research reactors being offered by several engineering firms within fixed price limits.

Dr. Wakefield was one of the leaders who anticipated the general need for research reactors. His purpose in having the book written was to aid universities and industries in making decisions on nuclear reactor installations. Although

(*Continued on page 42*)

OLDEST

...yet

KIELEY & MUELLER is the *oldest* control valve manufacturer in the United States.

However, K&M offers the *newest* diaphragm control valve design. The K&M Series 1400 diaphragm control valve was not *adapted* to high lift, it was *completely designed* for it. That's why K&M exceeds today by every measure of control valve performance . . . and valve manufacturing experience. That's why K&M is the valve *that likes to be compared.*

Write for Bulletin CV-53

77th Anniversary...Oldest U. S. Pressure and Level Control Valve Manufacturer

K&M

KIELEY & MUELLER, INC.

diaphragm control valves

64 Genung Street
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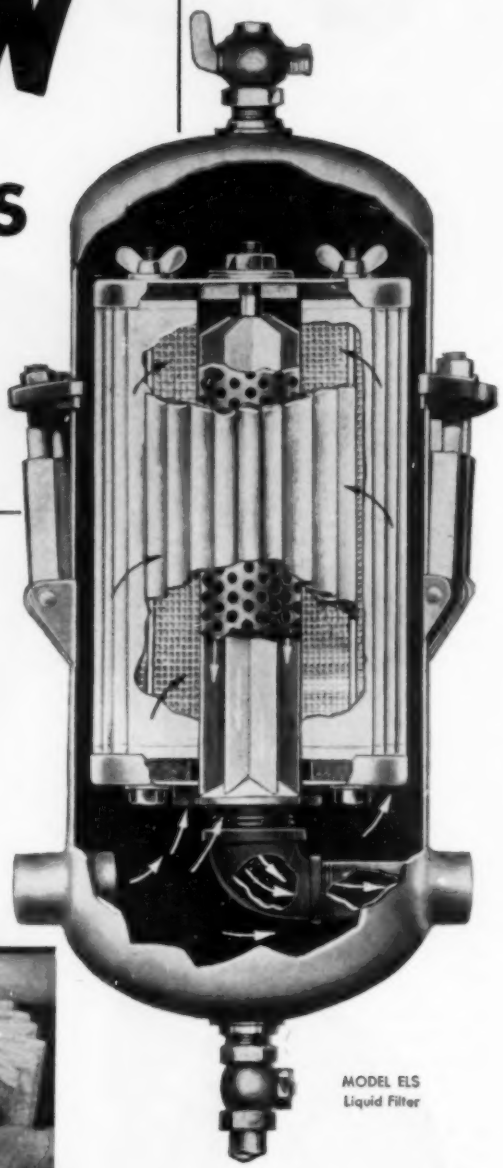

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Liquid Filter

Bring your liquid filtration problems to Dollinger engineers. Their specialized experience is available in recommending the most efficient and economical equipment for filtering liquids in a wide range of viscosities, temperatures, acidities, alkalinities, pressures and capacities.

Staynew exclusive design, permits use of *any medium in sheet form that can be crimped.* Metal, plastic, fabric, ceramic and metallic mesh media can be used for super-fine filtration.

Write us today outlining your specific liquid filtration problem. From our 30 years experience in liquid filtration, we have built up a vast file of helpful information. Any part of this information is yours for the asking—no obligation.

Staynew Radial Fin Construction provides the largest possible filtering area for available space. Slip-On Insert—exclusive in Staynew Filters—permits simple, inexpensive cleaning or replacement of media.

Representatives in Principal Cities

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DOLLINGER CORPORATION
79 Centre Pk., Rochester 3, N. Y.

ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

Pumping Progress Report

FOR HYDRAULIC ENGINEERS

An advertisement prepared by the Aldrich Pump Co., Member of Hydraulic Institute, U.S.A.

PUMP INSPECTION, MAINTENANCE AND REPAIR are jobs too frequently ignored in the design of production pumps. This has been verified by a survey of more than 15,000 pump installations. Speed and economy of maintenance was frequently quoted as a major factor in pump selection.

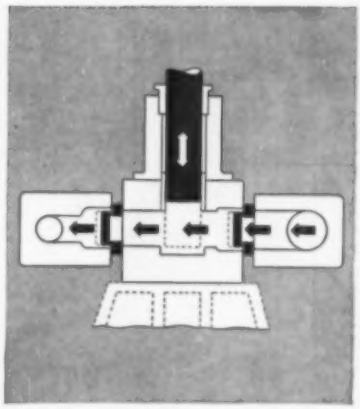
SECTIONALIZED FLUID-ENDS offer one of the best ways to guarantee both speed and economy in pump maintenance. As originated by ALDRICH Pump Co. Engineers, the Sectionalized Fluid-End comprises four main assemblies — the working barrel, suction manifold, discharge manifold and stuffing box.

SPEED IN MAINTENANCE is assured because of ease of accessibility of all wearing parts. Manifolds can be slid back on studs and valves removed as complete units. Split collar and flange connection of plunger to yoke permits easy removal of plunger.

ECONOMY OF MAINTENANCE results from speed in maintenance. Perhaps even more important is the simple fact that it is cheaper to replace a single section than a complete fluid-end. Another important economy is parts interchangeability. Among 3-, 5-, 7- and 9-plunger units of any series, wearing parts are interchangeable. Where a combination of multiplex pumps is required, this reduces spare parts stocks.

THE ALDRICH PUMP COMPANY is the originator of the DIRECT FLOW principle — a design innovation that utilizes the sectionalized fluid-end principle. Aldrich Engineers have become known as the people to take your tough pumping problems to. We have never turned down a challenge.

FURTHER INFORMATION can be had direct from the company. Tell us your problem and we'll send you Data Sheets describing the size pump we recommend to solve your problem. Address your request to: The Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.



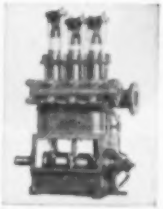
Aldrich Direct Flow Fluid-End Design

...for your tough pumping problems specify ALDRICH

The Direct Flow principle, an Aldrich design innovation, is a major forward step toward the solution of tough pumping problems of all kinds. Not only does it eliminate two right-angle turns in the fluid-end, but in addition makes possible complete Fluid-End Sectionalization. This is another Aldrich design innovation which permits economies of maintenance and repair offered by no other type pump.

CHECK THESE ADVANTAGES OF SECTIONALIZED FLUID-ENDS:

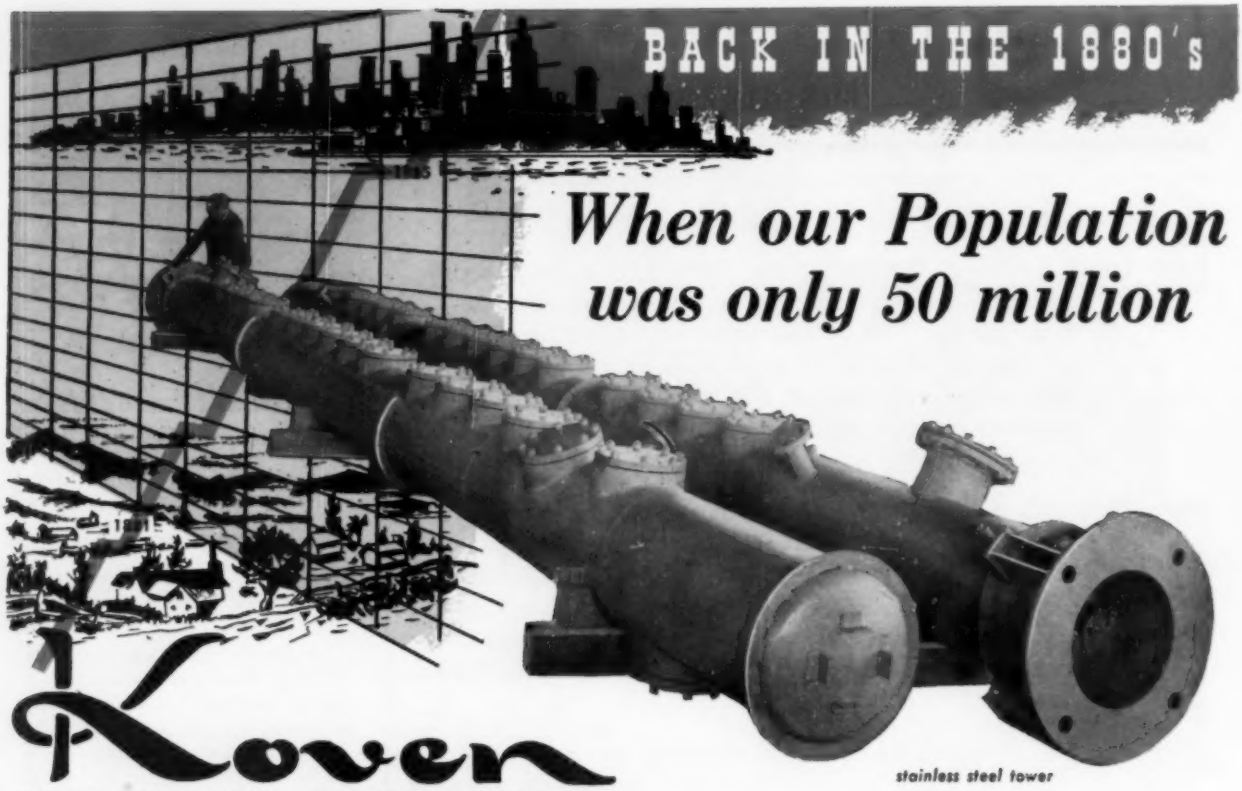
Less expensive parts replacement
Ease of inspection and maintenance
Interchangeable wearing parts
No special equipment for valve removal
Easily accessible stuffing boxes



Write today for Data Sheets describing the Direct Flow Pump Series.

THE ALDRICH PUMP COMPANY

Originators of the Direct Flow Pump
20 GORDON STREET
ALLENTOWN, PA.
Representatives in principal cities



When our Population was only 50 million

stainless steel tower

Koven WAS MAKING INDIVIDUALIZED CHEMICAL EQUIPMENT

Today's population of 165 million is proof of a potential realized — and the accomplishments of these millions continue daily to reaffirm our strength. KOVEN, one of America's leading steel fabricators, has been a part of the industrial growth and achievement which has accompanied our population increase. The results of almost 75 years of experience, research and skill are what KOVEN brings you. For fast, efficient, economical output; for individualized equipment—built to your exact needs—call or write for a consultation with a KOVEN representative—of course, no obligation. Send for Bulletin #550.

Specialists in intricate fabrication using:

stainless steel
monel
nickel
aluminum
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all clad materials

Fabrication to all A.S.M.E. Codes

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X-RAY INSPECTION FOR QUALITY CONTROL. KOVEN equipment in all metals and alloys includes: High pressure vessels, extractors, mixers, stills, kettles, tanks, stacks, breechings. Shop and field erected storage tanks 2 million gallons. High vacuum testing.

L. O. KOVEN & BRO., INC.
154-F Ogden Ave., Jersey City 7, N. J.

KOVEN FOR INDIVIDUALIZED EQUIPMENT SINCE 1881.

SEE . . . LEARN . . .
COMPARE

at the **25th**

EXPOSITION OF CHEMICAL INDUSTRIES

COMMERCIAL MUSEUM AND CONVENTION HALL
PHILADELPHIA DECEMBER 5-9

One profitable idea can make your trip to this Exposition worthwhile! And you'll learn *hundreds* of new ideas—a wealth of information will be presented under one roof! It's the one way you and your key men can do months of looking and learning in just a few days...and keep up with the important, ever-changing industrial chemistry scene! COMPARE the latest processing methods...SEE the year's biggest display of up-to-date materials and equipment...TALK with technical representatives of over 500 leading manufacturers.

Your Ticket to Philadelphia

YOU'LL save valuable time if you take advantage of this great opportunity to keep up with chemical engineering and chemistry! Fill out and mail the coupon on the other side to be sure of your advance registration and hotel reservations. No obligation, of course.

25th EXPOSITION OF CHEMICAL INDUSTRIES
PHILADELPHIA—DEC. 5-9

Management: International Exposition Company

"... it is difficult to exaggerate the value of a visit to the Exposition of Chemical Industries. No other agency is so successful in dramatizing to chemists, chemical engineers, production men and executives the advances and latest researches in their fields, so that they may apply, immediately, the newest techniques, equipment and materials to their individual production and research problems. Reduced costs and increased efficiency—these are the true themes of the Exposition of Chemical Industries, whose hundreds of instructive exhibits are ample evidence that these expositions more than fulfill their purpose. A visit to this always-worthwhile exposition is more important than ever in 1955, and is heartily recommended to all who believe in the need for continual progress in a highly competitive economy..."

—E. R. Weidlein, President
Mellon Institute, Pittsburgh
(Chairman, Advisory Committee,
25th Exposition of Chemical Industries)

COME to the

25th EXPOSITION OF CHEMICAL INDUSTRIES

COMMERCIAL MUSEUM AND CONVENTION HALL
Philadelphia December 5-9

THE Chemical Industries Exposition, with over 500 informative exhibits, is an unequalled opportunity for production men, executives, chemists and chemical engineers to get—first-hand—the latest information about chemicals and raw materials, plant processing machinery, materials of construction, materials handling, control instruments and other automation devices, laboratory apparatus, etc.

This year's Exposition—the 25th—represents over 40 years of progress in America's fastest-growing industry. Because it *is* so hard to keep up-to-the-minute—and because it's so important that you do—be sure to come, and bring your key associates, to the 25TH EXPOSITION OF CHEMICAL INDUSTRIES!

Exposition of Chemical Industries
480 Lexington Avenue, New York 17, N. Y.

Please register me in advance and send admission badge for the 25th Exposition of Chemical Industries.

Name_____

Title_____

Company Name_____

Company Address_____

_____

City_____ **Zone**_____ **State**_____

Company's Business or Product_____

(For any additional advance registrations desired, just write full information on your letterhead.)

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- Immunity to thermal shock
- No metallic contamination
- High thermal conductivity
- Low first cost and low maintenance
- Workability – readily fabricated and serviced in the field
- Sturdy, durable constructions
- Standard stock units
- Complete technical service

Manufactured only by NATIONAL CARBON COMPANY

■ Only the unique combination of properties provided by "Karbate" brand impervious graphite can virtually *eliminate* corrosion, contamination and thermal shock from your processes. You'll be pleased with the hidden economies you realize after replacing hitherto "satisfactory" process units with "Karbate" equipment.

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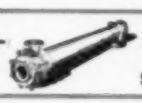
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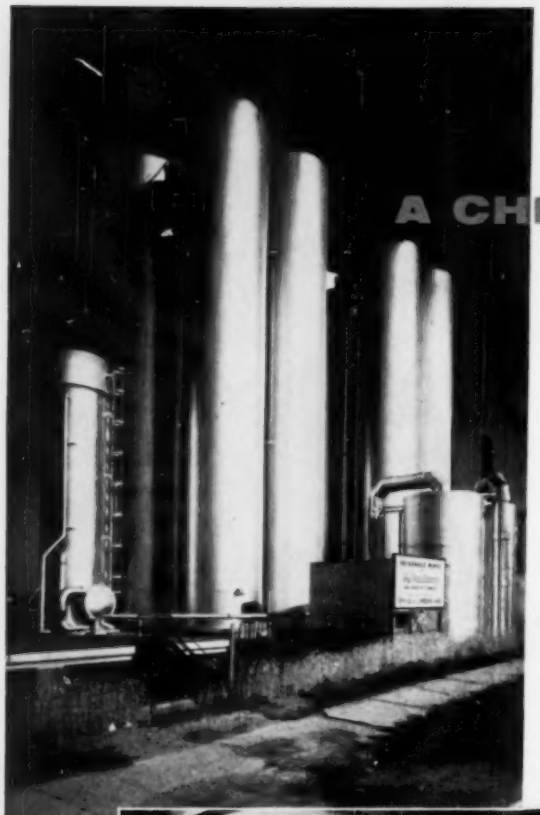

A CHEMICAL PLANT NEEDS . . .

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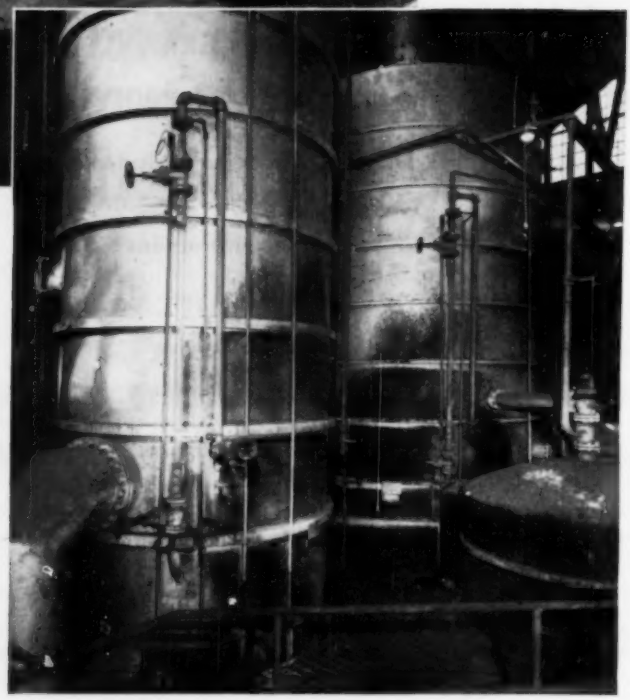

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Left: Conkey all nickel construction Triple Effect Evaporators producing 50 per cent caustic liquor.

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For further facts, write for Bulletin 16.

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"clean separation between vapor and liquid"

MARGINAL NOTES

(*Continued from page 32*)

several well-known authorities have contributed in the writing of the book, the reviewer believes that the book is not adequate. Some of the sections on radiation protection and nuclear instruments are commendable, when one considers the scope and the directed level of presentation.

One would welcome a revised, integrated edition in which the values of nuclear reactors are more completely described and illustrated, a wider representation of companies participating in nuclear reactor developments is included, types and costs of research reactors are given, and the current legal aspects are discussed.

A Glossary of Terms in Nuclear Science and Technology. American Society of Mechanical Engineers, New York (1955), 190 pages, $5.00. Prepared by National Research Council.

The first alphabetically arranged list of terms for use in science and technology, this list contains some duplications of definitions, but on the whole represents a coordinated effort towards standardization of terms used in fields of nuclear energy.

Principles of Nuclear Reactor Engineering. Samuel Glasstone *et al.* D. Van Nostrand Company, New York (1955), 872 pages, $7.95.

This work covers in a comprehensive treatment the technological and engineering principles which form the bases for current practice in the design, construction, and operation of nuclear reactors.

BOOK RECEIVED

Nuclear Geology, a symposium on nuclear phenomena in the earth sciences. Henry Faul, editor. John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., London (1954), 414 pages, $7.00.

Guide to Earning a Living. A complete survey of 119 careers in business, the professions, trade, agriculture, and government. Ed Cunningham and Leonard Reed. Simon and Schuster, New York (1955). 116 pages, $1.95 (paper), $3.95 (cloth).

Industrial Medicine on the Plutonium Project, survey and collected papers. R. S. Stone, editor. McGraw-Hill Book Co., New York (1951), 511 pages, $6.25.

ASTM Standards on Paint, Varnish, Lacquer, and Related Products. Prepared by Committee D-1. American Society for Testing Materials, Philadelphia, Pennsylvania (1955), 868 pages, $6.00.

A Laboratory Manual for Introduction to Chemistry. R. T. Sanderson and W. E. Bennett. John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., London (1955), 181 pages, $3.00.

Norton Products For The Atomic Program

Over half a century ago Norton Company first used electric furnace techniques to produce fusion-stabilized materials. Through the years Norton fusion-stabilized materials such as fused alumina, silicon and boron carbides, fused magnesia, zirconia, etc., have been made more valuable to industry and have been raised to new standards of quality, uniformity, and purity.

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Reactor Components

Stable boron compounds for reactor control elements and neutron shields. Ceramic and powder-metal fabricated components for fuel element applications.

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High-purity ceramic shapes, including crucibles and furnace components for processing metals and fuel elements.

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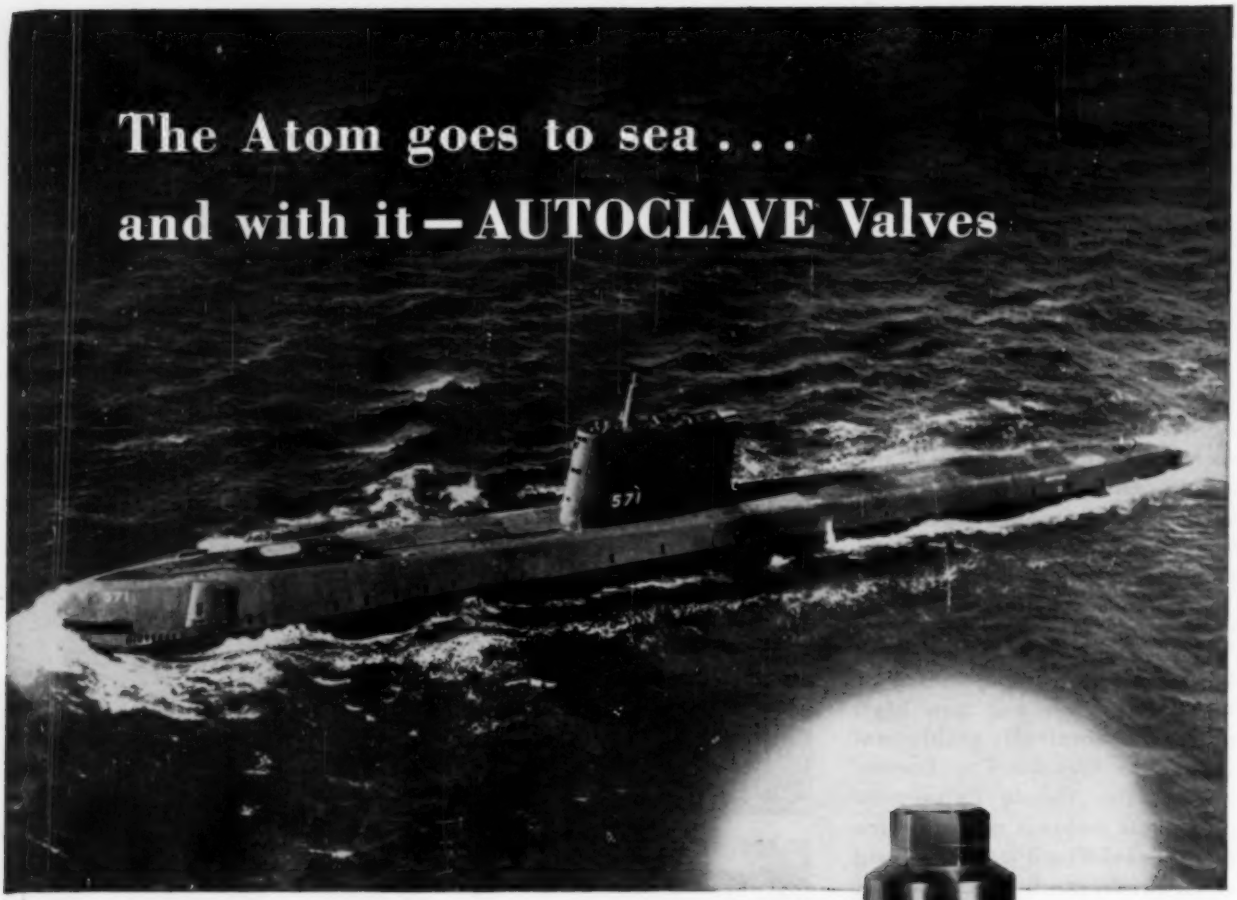

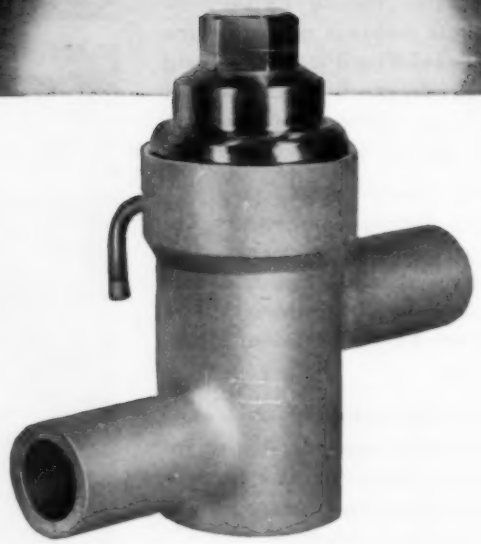

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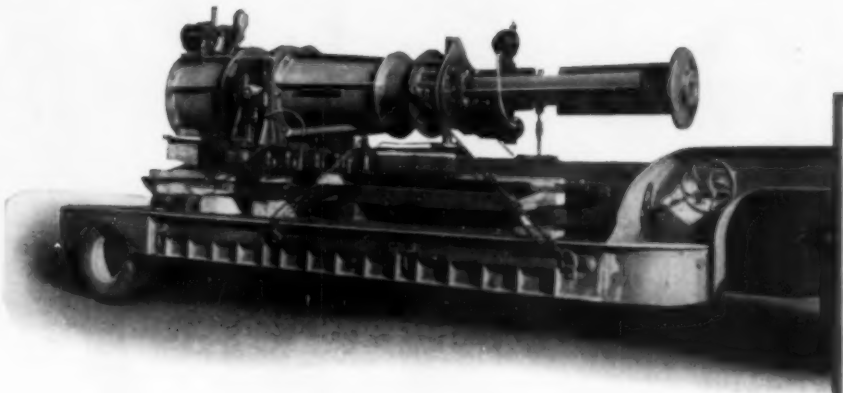

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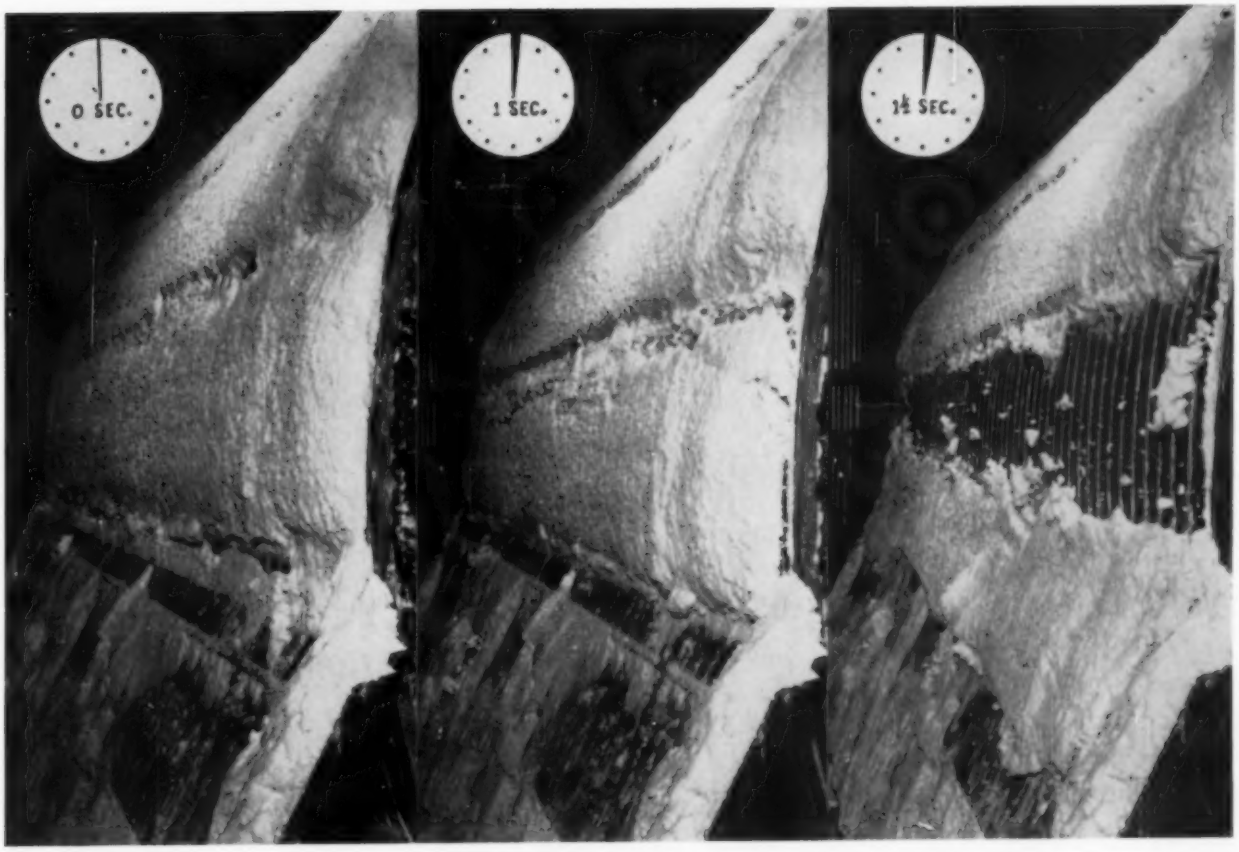

The high speed camera pictures show the Eimco Drum Filter with cake formed on the drum, cracked and leaving the panel clean.

SAVE WITH A SNAP!

Greater savings are being realized by many companies in filter media and filter down time where the use of a snap blow is practical for the product being filtered.

Snap blow on Eimco filters is accomplished by introducing high pressure air for a fraction of a second at the discharge point. This action on a heavy salt cake is shown above taken with high speed photography. The three successive pictures were taken only seconds apart as shown by the clock.

Advantages are in being able to move the scraper blade back so that it never touches the media and acts only as a deflector. The high pressure air helps keep the media free of blinding particles so that tonnage goes up — maintenance goes down.

Snap blow may be ordered with your Eimco filter, properly installed and regulated at the factory or, you may purchase a "snap blow" kit to install on your present fitler.

An Eimco engineer will be glad to advise the practicability of snap blow on your product. Write for more information.

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B-151

This customer saved 46% in freight charges

on these stainless steel plates

THESE STAINLESS sketch plates, produced by G. O. Carlson, Inc., saved the customer 46% in shipping costs. If he had bought rectangular plates and done his own cutting, he would have paid freight on excess material which he could not use.

Then too, cutting and machining facilities were quite limited at the job site. Time and money were saved by having Carlson cut and machine the plates to the accurate tolerances specified.

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CEP trends / METALS AND MINERALS

For a long time the emphasis in chemical research has been in the organic field, particularly in petroleum chemistry. The development of the petro-chemical industry from tiny beginnings a generation ago to the present stage of sales running into billions of pounds and billions of dollars has been one of the great American achievements in science.

Now there seems to be a marked renascence of inorganic chemistry, especially in some of the lesser known metals and their compounds.

Much of this has been stimulated by the tremendous discoveries in atomic science with its need for metals previously little known to industry. The jet age with its requirements for new metals and new fuels for rockets and guided missiles has been another important factor, and new needs for the electronic industry require new metals.

Though the production of metals may seem foreign to the chemical industry, chemical techniques are needed for producing them, and chemical firms are already leaders in a number of metal fields.

Leading Producers

Union Carbide & Carbon Corp. has long been the leading producer of ferro-alloys, more lately has turned to the production of pure metallic chromium on an industrial scale. Carbide and Du Pont are important producers of titanium wanted in increasing amounts by the air force. Dow, of course, was the pioneer and is now the only major producer of magnesium.

Atomic energy has uncovered needs for a whole series of metals little known outside scientific circles a few years ago. Besides the uranium fuel, an atomic reactor may need liquid sodium for heat transfer. It will use zirconium to jacket the fuel elements because this metal does not absorb neutrons and stands high temperatures and corrosion. Zirconium is now being produced by the Carborundum Co. but National Lead Co. and Union Carbide & Carbon are reputedly taking a look at possibilities in the field. Hafnium found along with zirconium does absorb neutrons and is used in controls in the atomic reactor, beryllium is finding new uses in atomic work, and boron is being considered as a coating for steel for use in shielding to protect workers from radiation.

Thorium which once had its chief use in old time gas mantles, made by Lindsay Light & Chemical, is being groomed as a possible supplement or competitor to uranium in atomic power plants. Lindsay is also doing new work on some of the "rare earths" which are really metals. Some of this strange group of elements have been in use on a small scale for years, cerium in lighter flints for example. But new techniques for separating these elements from each other, developed partly by the Atomic Energy Commission, have made it possible to evaluate new uses. Gadolinium for example is one of the best materials known for absorbing neutrons, might be a valuable shielding material if it could be produced in quantity at a reasonable price.

A little known metal, rhenium, a by-product of copper mining, had been a waste material for years. Rhenium has the highest melting point of any metal next to tungsten. Recent research has shown that it can be used as a superior substitute for tungsten in electronic tubes, and it lengthens the life of the tube. Selenium, not a metal, is going into rectifiers. Old fashioned and unromantic antimony has found a glamorous new use as a semi-conductor and may be able to substitute for scarce germanium in transistors, one of the newer miracles of the electronic industry.

Since the Geneva Conference on Peaceful Uses of the Atom a great deal of excitement has been generated around the light metal lithium as a material for putting the fusion reaction that takes place in the hydrogen bomb to work as a source of peace time power. From all indications any peace time use of the fusion process is many years off, but scientists do not think the problem is necessarily insoluble.

However, light lithium and another light metal, boron, are coming into prominence for other uses that may not be too far off. Lithium chemicals have been made for some time by Foote Minerals and by Lithium Corp. A number of important uses have been steadily expanding. Lithium compounds are important in the ceramics industry because they shorten the time needed for firing, make a better glaze. The compounds also go into enamels, lubricating greases, the making of drugs and vitamins.

The big romance however centers around the possible use of compounds of both lithium and boron in fuels or propellants or rockets and guided missiles. This is naturally in the realm of secrecy but it is an open secret that research is being done.

All in all, the surge in metals and minerals, touched off by atomic work, is moving rapidly in the areas of pure metal, metal compounds, coatings, and a whole gamut of heretofore unknown uses.

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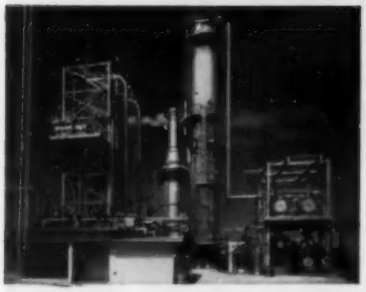
expands . . . modernizes . . . attains highest quality standards



McMURREY REFINING COMPANY
BOX 946
TYLER, TEXAS

June 22, 1955

SUBJECT: Blaw-Knox Company
Jobs #9220-1 to
9220-12, incl.,
9221, 9223 & 9292
at McMurrey Refining
Company, Tyler, Texas

Blaw-Knox Company
Chemical Plants Division
P. O. Box 778
Pittsburgh 30, Pa.

Attention: Mr. E. S. Wright,
Manager of Construction

Gentlemen:

We wish to commend you and your organization for the high quality workmanship, labor relations, customer relations, job cleanliness and efficiency on our expansion and modernization program which was started in early 1953 and is now nearing completion.

Your Construction Superintendent, Mr. R. E. Squire, has co-operated with our engineering department and operating department 100% and is to be commended for cost-consciousness and labor relations; we did not have a labor stoppage in the two year construction and revamp program.

We extend the invitation to you of calling on us at any time for recommendations on Blaw-Knox construction and/or Mr. Squire's ability as a job superintendent.

Yours truly,

McMURREY REFINING COMPANY

M. H. McMurrey, President

MHM:bjf

JOBS ENGINEERED AND COMPLETED BY BLAW-KNOX

9220-1	Electrical distribution system
9220-2	Utility systems and miscellaneous refinery facilities
9220-3	Rerouting McMurrey Creek
9220-4	Overall plant operation study
9220-5	Revisions to crude unit
9220-6	Refinery oil separators, blowdowns and flares
9220-7	Interconnecting process lines between units
9220-8	Storage and products lines from units
9220-9	Revamp #1 crude unit
9220-10	Revamp thermal cracking unit
9220-11	Revamp light ends facilities
9220-12	Revamp fluid catalytic cracking unit
9221	New 8,000 BPSD decarbonizing unit
9223	New 10,000 BPSD crude unit
9292	New aviation gasoline plant including a 1300 BPSD alkylation unit, related utilities systems, buildings, storage tanks and auxiliaries

A program of expansion and modernization of the McMurrey Refining Company, instituting the latest refinery techniques, has resulted in increased production, lower residual yields and higher octane ratings. Blaw-Knox engineers are proud to have played so important a part in engineering, revamping and constructing the various units and related systems.

BLAW-KNOX

BLAW-KNOX COMPANY

Chemical Plants Division

Pittsburgh 22, Pennsylvania

CEP what's in this issue...

(Continued from page 3)

U-233 and Th separation by extraction / 460
A. T. Gresky and others (U.S.A.)—While only a proposed method, which uses tributyl phosphate as a solvent, it is considered important enough to include along with the commercial processes described by Culler.

Separations processes other than extraction / 461
S. Lawroski (U.S.A.)—There are important ways to clean fuel other than by using solvent extraction. These, discussed in the paper, are precipitation, ion-exchange, fractional-distillation, and pyrometallurgical.

A pilot plant to recover wastes / 466
R. H. Simon and J. A. Consiglio (U.S.A.)—This paper gets down to actual equipment and other design considerations which you may have to face in processing radioactive materials.

The disposal of radioactive wastes / 470
Abel Wolman and A. E. Gorman (U.S.A.)—What are termed "radioactive wastes" will some day be vital raw materials—just as soon as we can find out how to use them.

Chemical processing in intense radiation / 474
R. P. Hammond (U.S.A.)—Did you know that radiation effects on most molecules are surprisingly small, and that most reactions proceed with utter indifference?

Irradiation of long-chain polymers / 476
A. Charlesby (U.K.)—This brief resume deals with how radiation is successfully—and not-so-successfully—being used to produce unusual crosslinkages in plastics.

Radiolytic oxidation of organic compounds / 478
Nathalie Bach (U.S.S.R.)—New ways of producing oxidation products of practical interest from chemically inert substances, are based on the formation of peroxides from oxygen by irradiation.

Cold sterilization of foods / 480
B. E. Proctor and S. A. Goldblith (U.S.A.)—This paper gets down to the basic aspects of what effect radiation has on the agents which cause food spoilage.

Reactor fuels / 482
J. P. Howe (U.S.A.)—Chemical engineers' interest in reprocessing spent fuels won't be complete unless they're familiar with the fuels which have to be worked with, and re-formed after reprocessing . . .

Detroit program / 57
L. R. Chrzan—Here's the last, final detail on the big annual meeting of the Institute to be held in the motor city.

Organic coatings indicator chart (Part III) / 64
Kenneth Tator—In this third reference sheet of a series, authority Tator discusses the selections indicated by the chart—gives a realistic picture of the limitations and advantages . . .

E.J.C. Nuclear Congress Program / 69
D. J. Lynds—The Congress, which we've been shouting about for months, is now described in latest detail . . .

Guide to Atomic Exposition / 69
D. J. Lynds and C. H. Talbott—Here is the Atomic Exposition guide you'll want to keep with you at Cleveland. Complete with floor plans, the exhibits are described in last minute detail *complete with names of principal persons in attendance!* If you're going to be a stay-at-home, fill out the special Data Service Card for results-by-mail!

Idaho chemical processing plant / 78
Described (at last) is the government's big facility.

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Koppers has developed this new method.

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Seven major firms join forces to build and operate this unit near N. Y.

Nation's eyes on bubbles & Kintner / 102
Prof makes Life Magazine!

And they called this Placid! / 104
Picture rushes from the Lake Placid meeting which may convey a very different meaning.

Industrial leader enters atomic fuel field / 106
The story behind Sylvania's fuel cleanup services-to-be.

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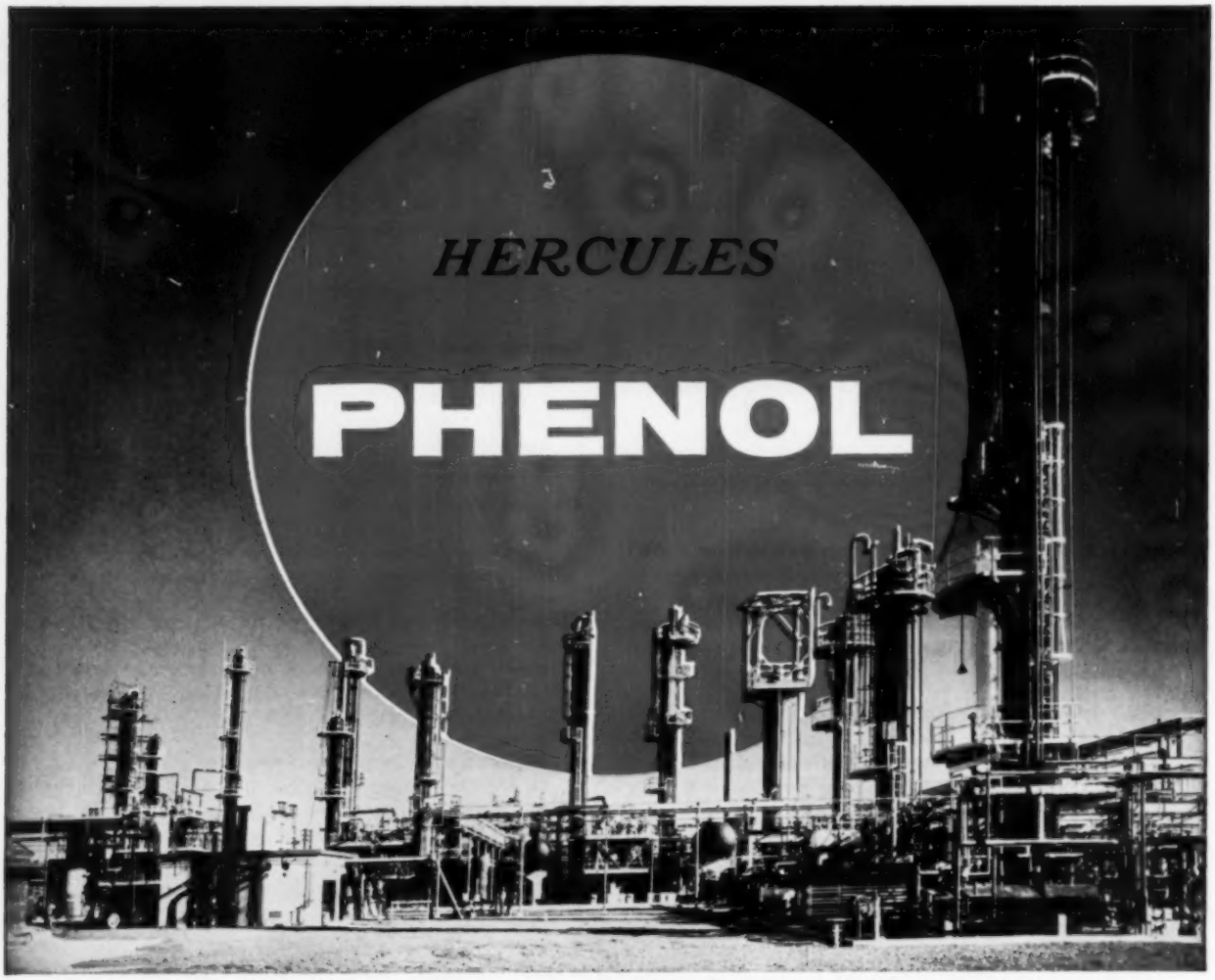

Hercules Powder Company plant at Gibbstown, New Jersey—largest facilities for the production of U.S.P. phenol on the eastern seaboard.

ANOTHER EXAMPLE OF "PARTNERSHIP IN PETROCHEMISTRY"

Many chemical manufacturers who have expanded their activities into petrochemicals, such as Hercules Powder Company, have found it advantageous to have The M. W. Kellogg Company work with them on their process or plant engineering problems.

One reason for this is M. W. Kellogg's 50 years of experience on comparable problems in petroleum refineries, and its more recent background in petrochemical plants. The latter includes ammonia facilities for Shell Chemical Company and Standard Oil Company of Ohio, ethylene plants for Imperial Chemical Industries Ltd., and the phenol-from-cumene project for B. A. Shawinigan Company.

The M. W. Kellogg Company can assume responsibility at any point. In Hercules' case, engineers of both companies collaborated in engineering the process and the mechanical design of this phenol-from-cumene plant. Hercules supplied the process for producing phenol-from-cumene. Kellogg supplied the process used for making the cumene feed. Kellogg erected the process units.

M. W. Kellogg would like to work in partnership with *you*, and invites you to review the facilities it can provide in keeping your initial investment and pay-out time to a minimum.

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CHEMICAL PROCESS DIVISION

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opinion and comment

"CRASH" NUCLEAR

We had been advised that a sizable amount of hitherto classified and thus unavailable information was released by our A.E.C. and by other nations at the Geneva Conference on Peaceful Uses of the Atom.

This was of course good news as we, among others, have long awaited the day when this would happen—both for the benefit of chemical engineering and for the atomic power program. For chemical engineers are expected to have a strong part in pulling that program away from the economic minus sign.

The problem has been how to get the inventive genius unique to the chemical engineering profession into high gear, with so much information about what has already been done, unavailable.

With the news of major release of information, many came to realize that the communication log jam would still not be free because of the "dilution factor." This refers to the data of chemical engineering significance literally buried in pounds and pounds of papers covering the myriad aspects of the nuclear field.

The longer we viewed the situation, the more apparent it became that someone should do a task in gleaning and sorting a prodigious amount of material within a reasonable time.

The Nuclear Engineering Division of the A.I.Ch.E. strongly supported C.E.P. in this decision to go ahead on the job, and, through its chairman R. P. Genereaux, offered to undertake the vital roles of selecting the material, setting the basis for condensation, and checking the technical accuracy of edited material.

And so it came about that C.E.P. undertook the most intensive project of its history. In carrying out the Nuclear Engineering Division's critically important part, credit and thanks are due Mr. Genereaux and staff at the Du Pont Company, G. F. Jenkins and staff at Union Carbide Nuclear Company, and Professor C. F. Bonilla of Columbia University.

All concerned sincerely hope that this special section will enable you easily and quickly to get a fairly detailed picture of the more important chemical engineering aspects of Geneva. This should provide a useful prelude to the Cleveland Congress. . . .

PROFESSIONAL STANDARDS

For well over a year Council of A.I.Ch.E. has been formulating a statement of policy on professional standards. This has just been made available for publication, too late for inclusion in this issue of C.E.P.

Consequently, the document entitled "Professional Standards—a Statement Sponsored by the Council of the A.I.Ch.E." will appear in the November issue. Preprints will be run off and will be available through the Secretary's office.

As the interest in this matter will be high, it was thought desirable to insert this announcement at the last minute, to tell you of an important event coming up.

J.B.M.

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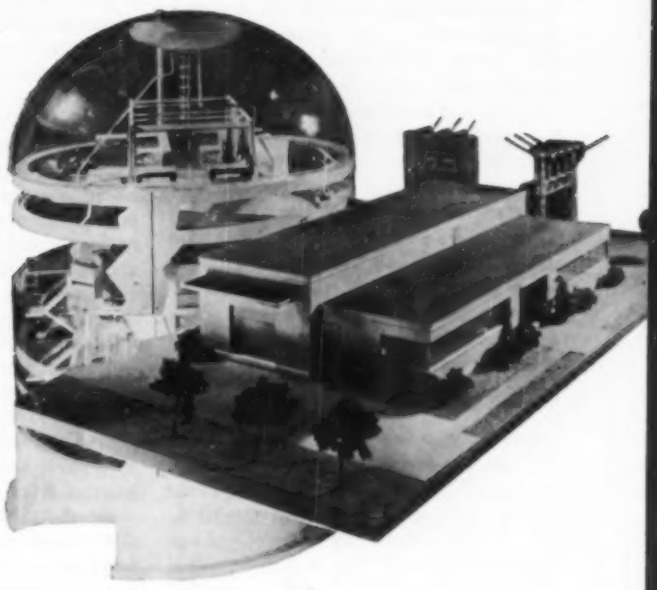
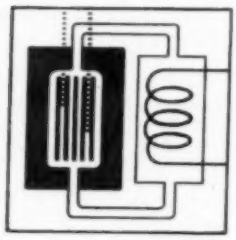
C. E. P.'s special review of

NUCLEAR ENGINEERING

To provide the chemical engineering profession with readily accessible, condensed, and yet authoritative information of importance from the Geneva Congress on Peaceful Uses of the Atom, the following 48-page special section has been prepared.

The Nuclear Engineering Division of A.I.Ch.E., *R. P. Genereaux, chairman,* undertook the task of establishing the pattern of condensation and verifying the technical accuracy following editing.*



reactors 

THE U. S. A. PRESSURIZED WATER REACTOR POWER PLANT

J. W. Simpson | Westinghouse Electric Corporation, Atomic Power Division,
M. Shaw | Reactor Development Division, U. S. Atomic Energy Commission
and Others

U.N.–A/Conf. 8/P/815

1. Introduction

The Shippingport power plant is sponsored to further the peacetime use of atomic energy in the field of electric power generation. The design, construction, and operation of this full-scale nuclear power plant will provide much knowledge in the fields of reactor physics, fuel element and core technology, and component and system design.

The plant will be built on a site of more than 400 acres located on the Ohio River in western Pennsylvania about 25 miles airline distance west of Pittsburgh. The immediate area surrounding the atomic power plant site is thinly populated and contains only one major industrial plant.

The reactor plant proper (PWR) utilizes a pressurized light water-cooled and moderated heterogeneous thermal-type reactor employing a combination of highly enriched and natural uranium fuel assemblies to produce heat sufficient for a net plant capability of at least 60,000 kw. electric power.

Illustration above shows model of experimental boiling water reactor being constructed at Argonne National Laboratry near Chicago. Courtesy Argonne.

2. General Description

BASIC PLANT CYCLE

The basic schematic diagram of the reactor and steam plant is shown in Figure 1. The nuclear reactor is the heat source and produces a minimum full power rating of 790×10^6 B.t.u./hr. This heat is produced in a nuclear core, which is a cylinder consisting of assemblies of enriched uranium in clad plates and natural uranium in tubes. The reactor vessel is a cylinder with a hemispherical bottom and a removable hemispherical top closure. Coolant enters through four nozzles at the bottom of the reactor vessel and leaves through four nozzles at the top.

The reactor plant consists of a single reactor heat source with four main coolant loops. Three of these loops are required for producing the 60,000-kw. minimum design power. Each loop consists of a single-stage centrifugal canned-motor pump, a heat-exchanger section of a steam generator, 16-in. gate-type isolation valves, and the necessary 18-in. O.D. interconnecting piping.

High purity light water serves as both coolant and moderator in this plant. This water is under a pressure of 2,000 lb./sq.in. The flow through the nuclear core is 45,000 gal./min. for three loops. At full power the nilet water temperature to the reactor is 508° F. and the outlet temperature is 542° F. The water velocity in the 18-in. pipes is approximately 30 ft./sec., with a velocity of between 10 and 20 ft./sec. in various parts of the nuclear core. The total pressure drop around the main coolant loop is 105 lb./sq.in., and this drop is divided roughly equally between core, steam generators, and piping.

The coolant enters the bottom of the reactor vessel where 90% of the water flows upward between the fuel plates and rods, with the remainder by-passing

* Mr. Genereaux and staff at the Du Pont Company, G. F. Jenkins and staff at Union Carbide Nuclear Company, and Professor C. F. Bonilla of Columbia University, performed these functions for the Division.

All literature references and some tabular and graphic matter had to be omitted. Further details will be available in the 16-volume set of Proceedings to be issued by U. N.

the core in order to cool adequately the walls of the reactor vessel and the thermal shield. After having absorbed heat as it goes through the core, the water leaves the top of the reactor vessel through the outlet nozzles. It passes then through two 16-in. isolation valves in series and goes through the heat-exchanger section of the steam generator. The water then flows through the canned-motor pump and back through the inlet isolation valve to the bottom of the reactor vessel, completing the cycle.

Isolation valves are located immediately adjacent to the reactor inlet and outlet nozzles of each of the four loops. These valves permit isolation of any loop of the reactor plant, to provide maximum protection to the reactor and so that maintenance can be performed while the remainder of the loops are in operation. Adequate shielding is provided to permit this.

The main coolant flows through the inside of many hundreds of small stainless steel tubes in the heat-exchanger section of the steam generators. These heat-exchanger tubes are surrounded by the water of the secondary system, which is heated by the primary coolant in the tubes. Wet steam is formed, which passes upward through the risers and enters the steam-separator portion of the steam generator. Here the moisture is removed and returned to the heat-exchanger section through the downcomers. The dry and saturated steam at 600 lb./sq.in.abs. at full power leaves the top of the steam separator and goes to the steam turbine.

SELECTION OF MAJOR PLANT PARAMETERS

The selection of the primary and secondary system temperatures and pressures is a compromise of many conflicting factors. Steam-system pressure and temperature should be as high as possible, giving the most efficient utilization of nuclear fuel and, in the pressure range under consideration, the lowest cost for steam-plant equipment per kilowatt. The cost of the primary-system components increases with pressure, and 2,500 lb./sq.in. represents about the highest practical pressure with present-day technology. The nominal operating pressure consistent with a 2,500-lb./sq. in. design pressure is 2,000 lb./sq.in., for which the saturation temperature is 636° F.

Owing to lack of basic knowledge on pressurized water reactor plants, a considerable number of rather costly safety features, such as the plant container, have been included. The experience gained in operation of this plant will enable such features to be evaluated and therefore possibly removed from future plants.

3. Major Components

DESCRIPTION OF PLANT CONTAINER

The nuclear part of the power station is housed in four steel plant containers which, in turn, are in concrete compartments partially below ground level.

The reactor vessel is housed in a spherical shell 38 ft. diam. with an 18-ft. cylindrical dome on the top to accommodate the extra height of the control drive mechanisms. Located on each side of the sphere is a 50-ft. diam. cylinder, 97 ft. long, in which are located two of the primary coolant loops and their associated equipment. An additional auxiliary container is located between the nuclear equipment containers mentioned above and the turbine generator. This container is a cylinder 50-ft. diam. and 147 ft. long. The coolant pressurizing tank and other minor auxiliary equipment are located in it.

An air-cooling system is designed to control the air temperature within the plant container to 122° F. maximum and to provide means for ltering all air exhausted from the plant container.

Access to the vapor container is permitted and interlocking access doors are provided so that the integrity of the container is not jeopardized by conventional entrance doors.

DESIGN CONSIDERATIONS

The problem of containment is derived from safeguard considerations for protection of personnel against radioactive fallout outside the 400-acre Shippingport exclusion area. The container is designed to prevent escape of any radioactive gases or vapor containing fission products that may be accidentally released as a result of any major plant casualty.

The container is designed to handle the release of the energy in the approximately 20,000 gal. primary coolant water at 535° F. average temperature and 2,000 lb./sq.in. pressure, the heat energy stored in the metal of the plant, and the energy of the worst conceivable chemical reaction between the zirconium and water.

SHIELD

The radiation level permitted varies depending on the amount of access required. In operating spaces the radiation level is held to less than 2 mr./hr. Where only intermittent access is required the radiation is maintained at less than 5 mr./hr. Areas occupied infrequently and for short periods may have a radiation level as high as 50 mr./hr.

The reactor vessel is surrounded by neutron shield tank providing a 3-ft. thick water layer. Other internal shields are concrete. In general, the external shield consists of the concrete structure surrounding the plant container.

Radiation-monitoring equipment is provided as required throughout the plant area to determine the existing radiation levels and to warn the operating personnel of any unusual conditions.

SITE FACILITIES

The fuel-handling building, which is the largest building on the site, is 44 × 182 ft. with a height of 60 ft. A 100-ton crane is provided for removing the reactor-vessel closure and the core as a complete unit if desired, or any fuel assemblies.

The fuel assemblies will be removed from the reactor vessel under water and moved to the appropriate section of the canal for storage, further disassembly, repair, or examination.

REACTOR VESSEL

The reactor vessel shown in Figure 2 has an over-all height of 33 ft., with a cylindrical section with an internal diameter of about 9 ft. and a nominal wall thickness of 8½ in. The vessel has a bottom hemispherical head and a standard bolted and flanged top closure modified to use a gasket or a seal weld for the final sealing. The total estimated dry weight of the reactor vessel is 250 tons.

The vessel is formed of carbon steel plates and forgings with a 0.25-in. stainless-steel cladding. The flanges for the closure will be 9 ft. I.D. and 23 in. square in cross-section, with each flange weighing approximately 75,000 lb. The hemispherical closure head will be forged and have a final thickness of approximately 10 in., with adequate reinforcement for the 24 control-rod penetrations and the 9 fuel-port tubes. The closure head will be held to the vessel by forty-two 6-in. diam. studs. The bottom head will be 6 in. thick.

The cylindrical portion of the vessel is made in two courses; each course consist of two semicircular plates welded together. The cylindrical body of the vessel will require three circumferential welds and two longitudinal welds.

STEAM GENERATORS

Steam generators of two different types are used so that experience can be gained in the design, manufacture, and operation of both types to give more knowledge on which to base the design of future plants.

4. Core Design

MECHANICAL DESIGN

The active portion of the nuclear core is in the form of a right circular cylinder 6 ft. mean diameter and 6 ft. high. To minimize the amount of enriched U^{235} used, the core consists of some highly enriched seed and some natural blanket assemblies. The seed assemblies are located in a square annular region about 6 in. thick. The area inside and outside the annulus is filled with natural uranium oxide subassemblies.

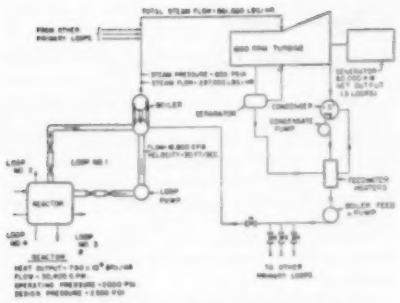


Fig. 1. Schematic diagram of plant.

Each seed subassembly consists of several plates welded together to form a box. Four of these box-type units are welded together, with separation maintained by spacers to form a central cruciform-shaped area. In each of these areas is located a cruciform-shaped hafnium control rod.

The blanket assemblies use a rod as the basic element. These rods are Zircaloy-2 tubing with a 0.413-in. O.D. and a 0.028-in. wall. The tubes are filled with UO_2 pellets. These are assembled into bundles of 100 rods each; the assembly is made by mechanically fastening together a stack of seven bundles, each about 10 in. long, for a total of about 6 ft. The individual rods are welded to plates at each end. Holes are drilled in the plates between the rods to permit the flow of coolant water.

The bottoms of the blanket assemblies are provided with the necessary orifices to distribute properly the coolant flow. In addition a perforated flow baffle just below this plate insures uniform distribution of coolant and adequate mixing of the water that enters the vessel through the inlet nozzles. Provisions are made for removing any individual seed or blanket assembly.

A major problem in the operation of a nuclear-power plant is the difficulty of determining exactly what is taking place within the reactor vessel with respect to coolant flow, boiling of the coolant, temperature of the fuel elements, or failure of these elements. Suitable instruments for making these determinations are therefore provided.

PHYSICS DESIGN

The seed assemblies contain a total of 52 kg. of enriched U^{235}, and the blanket contains 12 tons of uranium in the form of UO_2. At the start of reactor life approximately 60% of the power will be produced in blanket assemblies and 40% in the seed assemblies. The power distribution is a function of reactor life, inasmuch as the reactivity of both the seed and blanket vary with reactor life. The percentage of power produced in the blanket is expected to increase with time. Obviously, power distribution is also a function of the reactor temperature and the position of the reactor control rods.

In the pressurized water reactor most of the power comes from the fissioning of U^{235}. However, approximately 8% comes from the fast fissioning of U^{238}, and a substantial fraction comes from the fissioning of plutonium. This latter effect increases with the lifetime of the reactor and is expected to reach a substantial fraction after 3,000 mw. days/ton average burn-up in the blanket assemblies. At the start of life, approximately 0.8 atoms of plutonium are formed for each atom of U^{235} that is fissioned.

THERMAL AND HYDRAULIC DESIGN

To prevent nucleate boiling, the maximum coolant temperatures must be below 636° F., which is the saturation temperature for the 2,000 lb./sq.in. operating pressure.

reactors

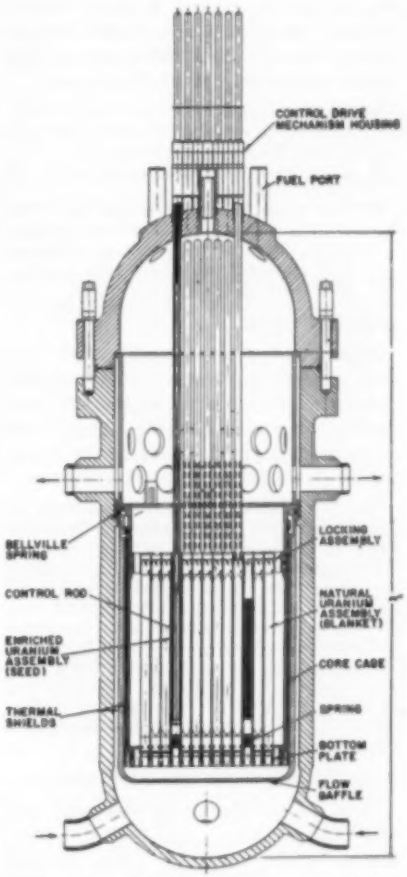
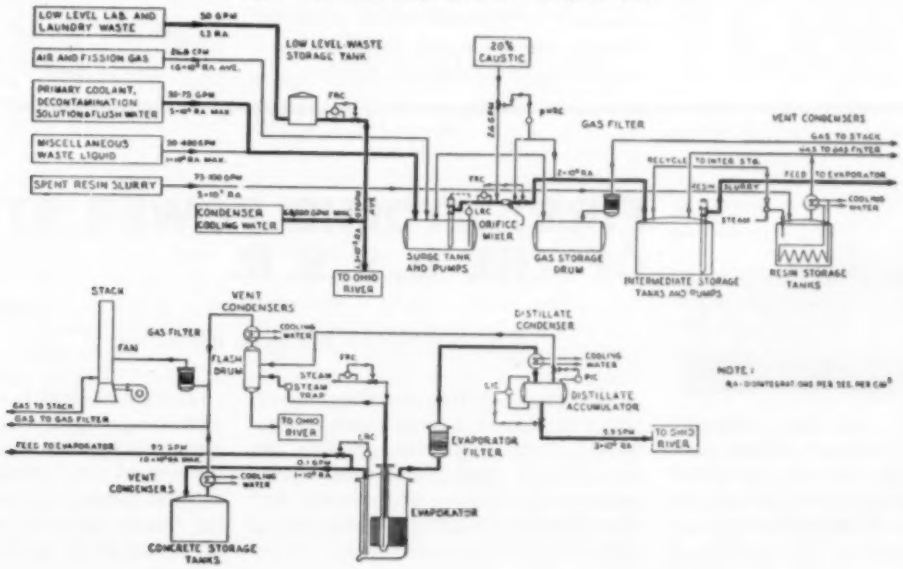


Fig. 2. Longitudinal section of reactor vessel.

Fig. 3. Schematic diagram of waste disposal system.



5. Primary Auxiliary Systems

PURIFICATION SYSTEM

A fraction of the coolant that passes through the nuclear core must be purified to limit the activity build-up of the long-lived impurities in the water. This is done by passing a certain quantity of the coolant through a by-pass demineralizer, which removes soluble and insoluble matter. The following are the design characteristics of the system:

a. Corrosion rate of 10 mg./square decimeter/mo. for stainless steel and 100 g./day for core fuel material
b. Flow rate for each demineralizer of 20,000 lb./hr.
c. The resin is of the mixed-bed type, with a capacity of 12 g.-equivalents/cu.ft., and a temperature limit of 130° F. max., with an area loading of 5 to 7 gal./(min.)/(sq.ft.).

SAMPLING SYSTEM

The sampling system removes homogeneous samples from the purification system before and after each of the two demineralizers to provide information on conductivity, *p*H, impurities, and dissolved gases.

The *p*H and conductivity measurements provide a means for determining the alkalinity or acidity of the primary coolant. These measurements also provide an indication as to when the demineralizer resins are spent and require replacement. The suspended solids are collected and measured and show the effectiveness of the demineralizers. Samples are withdrawn for dissolved gas analysis on hydrogen, oxygen, and fission gas products. The effluent from a sample room is discharged into the waste-disposal system.

COOLANT DISCHARGE AND VENT SYSTEMS

The coolant discharge and vent system is designed to collect radioactive waste material from various sections of the primary plant and to convey these materials to the waste-disposal influent tanks. The discharge system contains: a 3,600-gal. flash tank, which is used to depressurize and cool these materials before they are discharged from the vapor containers; and a 7,000-gal. blow-off tank, which is designed to contain all of the steam or reactor coolant discharged through various primary plant relief valves. The discharge and vent system must be operated in order to drain a loop, to maintain the fluid level in the pressurizer within the design range, and to bleed off reactor coolant during plant warm-up.

WASTE DISPOSAL SYSTEM

The activity in the ion-exchange resin (from the purification system), the decontamination fluids, and primary system effluent will be too high to permit dumping in the river. The volumes involved make packaging and subsequent disposal at sea infeasible. The waste-disposal system, Figure 3, now being developed will consist of two-stage evaporation to reduce bulk, and subsequent underground storage of high-activity evaporator bottoms at the site. Spent resin from the demineralizers will be transferred by flushing in the form of a slurry directly to underground storage. Provision for collection and storage of radioactive gases is being made. Dilution and discharge through a vent stack will be used when meteorological conditions permit. The evaporator feed will be from 9,000 to 21,000 cu.ft./month, depending primarily on decontamination procedure. Evaporator vapor will be condensed and then diluted with condenser cooling water before release to the river. The permissible activity released to the river is being taken at 10% of the standard tolerance. A study is underway to determine the most economical method for disposing of combustible radioactive waste; methods being considered are an incinerator at the site, or baling and shipping for disposal at sea. High- and low-activity laboratory wastes will be separated at the source and processed through the evaporator or diluted and dumped as dictated by the activity.

6. Reactor Control

EMERGENCY SHUTDOWN SYSTEM

Loss-of-flow accidents in PWR fall into two categories: (a) those that require fast action from the shutdown system, such as the loss of all pumping power, and (b) those for which an attempt must be made to keep the plant in operation by reducing generated power and load.

Start-up accidents can occur if the reactor period is not limited to a safe minimum value.

Safe maximum level in PWR is a function of coolant flow rates or, equivalently, of the number of pumps in operation at any instant. The safe maximum power is therefore threatened in any accidents involving loss of flow. However, even with undisturbed flow conditions, there exists the danger of the power level being raised inadvertently or accidently beyond safe limits.

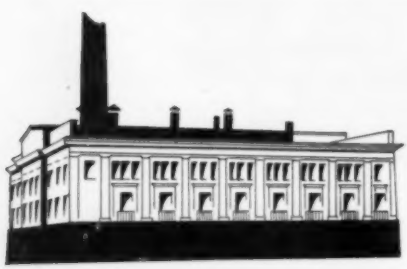
Cold-water accidents can occur if the water of a cold loop (or loops) is admitted to the reactor. The severity of the accident is a function of the ensuing reduction in coolant temperatures and of the magnitude of the negative temperature coefficient of reactivity.

Leaks in the primary coolant system or failure in the pressurization system can cause the pressure to drop to values that result in intolerable boiling at operating temperatures.

MOCK-UPS AND TESTS

Because of the severe space and thermal limitations associated with the design of a compact power-producing core, many of the mechanical and thermal features are new in concept and require mocking up and testing prior to final fabrication. For example, the adequacy of the reactor vessel head and the handling tool are best established by use of model and full-size mock-up tests. In order to indicate the magnitude of this work, listed below are some of the tests required to establish important design information to confirm the adequacy of reactor components:

Vibrational, thermal distortion, stress concentration, wear of materials in hot water, fatigue limits.



FIRST ATOMIC POWER STATION OF THE U. S. S. R.

U.N.–A/Conf. 8/P/615

D. I. Blokhintsev and N. A. Nikolayev

Construction of the first industrial atomic power station in Russia with an output of 5,000 kw. was completed and was generating electricity from the energy of fission of uranium nuclei in 1954.

The heart of the operating atomic power station is a pressurized, water-cooled, thermal uranium-graphite reactor with a rated heat-generating capacity of 30,000 kw. The average flux of neutrons is 5×10^{13} neutrons/(cm.)/(sec.).

The atomic fuel is enriched uranium containing 5% U^{235}, the total charge being 550 kg. The heat transfer system consists of two circuits: the water of the first circuit, which circulates through the reactor, is under a pressure of 100 atm., and gives up its heat through a

system of heat exchangers to the water of the second circuit which, transforming into steam, drives a 5,000 kw. turbogenerator.

The use of a two-circuit system of heat transfer eliminates the possibility of radioactive contamination of the turbine and its connections. This results in making the tending of the turbine and all its auxiliary equipment exactly the same as at conventional heating and power plants, biological protection (from radioactive radiations) being unnecessary for this equipment.

In this reactor the burn-out of U^{235} is 15%. Owing to the low resonance capture, the production of plutonium from uranium^{238} is low and equals only 0.32. Fast neutron multiplication is practically absent.

Thus, the reactor of the atomic station described works almost exclusively by burning U^{235}, the degree of enrichment decreasing during the operation of the reactor from 5 to 4.2%.

General Features

The principal features of the reactor design were determined by the properties of the materials chosen.

The reactor is encased in a hermetic, cylindrical steel jacket mounted on a concrete foundation. The jacket is filled with graphite brickwork with proper clearance. To avoid burn-out of the graphite the jacket is filled with helium (or nitrogen). A total of 128 fuel channels pierce the central part of the graphite brickwork. Each fuel channel is a long graphite cylinder containing thin-walled steel tubes carrying the primary circuit water. The water passes through the upper head of the channel connected with the inlet and outlet headers, then runs down through the tubes and returns up, flowing over the surface of the uranium fuel elements.

The uranium fuel elements form a cylindrical (150 cm. diam. and 170 cm. high) active zone of the reactor, enclosed by a graphite reflector.

The flow and temperature of the water are recorded for each channel. The indicating instruments are located on the central panel and are connected with the safety rods which stop the chain reaction when the water flow transcends the prescribed limits or when the temperature rises above the allowed level.

At a pressure of 100 atm. water boils at 309° C. If the temperature of the water in the channel reached this level, its boiling would cause a sharp heat-removal decrease and, consequently, overheating and possible destruction of the fuel element. It is therefore important to control the outlet temperature of the water since this reflects the conditions in the channel. There is, in addition, a separate plug panel for measuring the absolute temperature of the water in any desired channel.

Temperature measurement is supplemented by water flow measurement. A decrease in the flow of water in a channel leads to a rise in outlet temperature; an increase indicates a rupture in tubes of the channel or its connections. All these deviations are dangerous and lead to a shutdown of the reactor (termination of the chain reaction) by means of the safety rods.

To prevent rapid filling of the reactor with water, each channel is equipped with a cut-off device and a nonreturn valve to interrupt the flow of water from the header. A small water flow remains to remove the residual heat produced by radioactive decay of the fission products.

The radioactivity of the water and gas in the reactor is constantly measured. The central control panel has indicators showing the total flow of water through the reactor, its pressure and temperature in the inlet and outlet headers.

To compensate the excessive activity of the reactor, eighteen boron carbide control rods are installed in the reactor.

If the chain reaction increases, the atomic regulation rods go down, and if it falls off, they rise. One pair of rods works at a time, while the other pair is in reserve. These regulators maintain the chain reaction at prescribed level to within 3% accuracy.

The reactor has a number of devices for physical investigations and tests of materials.

There are in the reactor six curved channels and three straight horizontal channels; all are designed for nuclear physical research.

Biological shielding is ensured by a side water shield 100 cm. thick and a concrete wall 300 cm. thick. In the upper part of the reactor, intensification of the graphite reflector, the upper steel cover of the apparatus, and a cast-iron plate act as shielding.

Description of the Power Section

The primary heat transfer agent is water which circulates under high pressure. In the steam generators secondary heat transfer agent water is converted into steam which goes to the turbine. The entire primary circuit is made of stainless steel and is situated behind the so-called biological shielding.

The water of the primary circuit is heated in the reactor channels to a temperature of 260-270° C. and passes to the steam generators from a header. There are eight such steam generators coupled in pairs in the shielded boxes. At peak power output, three pairs of steam generators are in operation and the fourth pair is in reserve. Each steam generator consists of a water heater, a water evaporator, and a steam superheater. The water of the primary and secondary circuits in the steam generators moves according to the countercurrent principle.

The water of the primary circuit leaves the steam generators at a temperature of about 190° C. and enters the inlet pipes of the four main circulation pumps. Three are in operation at peak power output, ensuring water consumption of about 300 tons/hr.; the fourth pump is in reserve.

There are special feed pumps for adding fresh water to the primary circuit. These same pumps automatically feed water to seals of the main circulation pumps to maintain pressure in the seals 0.5 atm. above the water pressure in the pump. This prevents the radioactive water in the main pumps from penetrating along the shaft.

As the water of the primary circuit moves away from the reactor, its activity gradually falls. At the outlet of the reactor it is due to oxygen activity (0.2 curie/l.) with a short decay period (7 sec.), whereas at the inlet of the reactor the activity of the water (2.10-5 curie/l.) is due basically to impurities.

To ensure compensation for changes in water volume during heating or cooling and to maintain for a certain period of time the pressure in the circuit in the case of a leakage, the arrangement is supplied with volume compensators, which are circular tanks connected with cylinders of compressed gas.

Along the primary circuit line, on the by-pass, there are contact units for burning the explosive mixture which may arise through water decomposition because of neutron radiation.

The equipment of the secondary circuit is of the conventional type, inasmuch as radioactive contamination from the primary circuit water is not considered likely.

At peak power output of the station, the three operating groups of steam generators produce 40 tons of steam/hr. at a pressure of 12.5 atm. and at a temperature of 255-260° C.

The station is provided with various electrical equipment, including a storage battery capable of feeding the electric motors of the main circulation pumps at low speed for several hours, which might be needed in an emergency.

Radioactive water (when the water is let out of the primary circuit) is discharged to storage tanks, where its activity is reduced to the safety level by dilution and by decay.

Atomic Power Station Operation Experience

Since the atomic power station was started up, it has been tested in various operating conditions and has produced about 15 million kw.hr. of electric energy. This operating experience has made possible the following conclusions.

1. During operation of the station there has not been a single case of fuel element failure. In view of the changes that graphite undergoes in a neutron field, it might have been feared that the holes in the graphite brickwork would become clogged with fuel elements.

Experience in channel replacement showed that the fuel channels are easily removable.

The temperature of the graphite proved to be above the rated temperature and at the hottest points reached 650-700° C.

Operation experience has shown that control makes it possible to ensure rated power of the apparatus for a long period (from loading to loading).

Unloading of the uranium fuel elements from the reactor is done by sections with a view to economizing atomic fuel. The reactor is simultaneously loaded up with fresh heat-generating elements, and the less burnt-up periphery elements are moved to the center of the apparatus. This resulted in extending the operation period of the fuel elements and increased the burning depth of U^{235} to 20%.

The elements are replaced once in two months, requiring two to three days.

A start-up of the reactor from zero to the rated power takes approximately half an hour and is the most important operation, especially when the reactivity of the reactor is not precisely known. At present, work is proceeding on automatic start-up project.

2. The main technological equipment of the station (main circulation pumps, booster pumps, steam generators, volume compensators, etc.) worked without failure.

High purity of the water of the primary circuit is necessary for successful operation of the reactor. Bidistillate, with which the primary circuit was filled, has a dry residue of less than 1 mg./l.

3. The gamma radiation intensity in the main hall, at nominal reactor power, has not exceeded 0.1 μr./sec. which is considerably less than the biological tolerance dose. When the apparatus is being unloaded, the protection walls of the hall safeguard completely work in the surrounding rooms. Protection of the rooms of the steam generators, the pumps, and pipelines of the primary circuit likewise safeguard the service rooms from radiation.

For a limited period of time one may also enter the halls where this equipment is located (radiation does not exceed 6 μr./sec.).

The activity of the gas passing into the ventilation funnel was due basically to the activity of the argon of the air. Measurements show that the selected height of the ventilation pipe is sufficient to ensure safe conditions for the surrounding population as was provided for in the project.

The activity of the water drained out of the primary circuit is 10 curie/l. as to sodium and manganese. After its retention in storage tanks and after dilution with pure technical water, the activity of the drained water is easily brought down to the necessary biological level.

Comparison of Atomic and Coal Electric Power Station

The cost of 1 kw.hr. of electric energy produced by the first atomic power station exceeds considerably the average cost of 1 kw.hr. in powerful heat power stations in the U.S.S.R. In 1953 the cost of electricity in the thermal power stations of the Ministry of Electric Power Stations was 10 kopeks/kw.hr.

An analysis of the cost of 1 kw.hr. of electric energy carried out in the case of an atomic station of 100,000 kw. with account taken of improvements, shows that the cost of electric energy in this case is reduced considerably.

An increase in the reactor size will permit enrichment of the uranium loaded into the reactor to be lowered. Calculations show that for the work of the two reactors of this large station up to 20 tons of uranium a year will be required. The uranium will have to be enriched to 2.5% with the uranium isotope 235 instead of the 5% enrichment at the first atomic power station.

Reduction of enrichment lowers considerably the fuel component of the cost of 1 kw.hr. of energy produced by the first atomic power station.

At present, in the U.S.S.R. various-type atomic power stations with a capacity of 50-100 thousand kw. and more are being designed. Economic calculations show the possibility of producing electric energy at such stations at a cost of between 10 to 20 kopeks/kw.hr.

Reactor Type

FAST NEUTRON REACTORS

Fast neutron reactors make possible full utilization of the natural resources of the whole of uranium and not only of its 235 isotope. Fast neutron reactors should therefore be considered a major part of the nuclear power development program. However, construction of nuclear power stations with fast neutron reactors is still a remote prospect.

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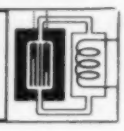
reactors



THE GRAPHITE-MODERATED, GAS-COOLED PILE— ITS PLACE IN POWER PRODUCTION

Christopher Hinton

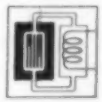
United Kingdom Atomic Energy Authority

U.N.–A/Conf. 8/P/406

In every engineering development there is an element of chance which may sway the balance between the choice of one design or another. In 1946 it was the intention that Great Britain should build reactors of the original Hanford type, which is graphite-moderated and water-cooled and cannot be made inherently stable if operated solely on a natural uranium fuel. Because of this, large safety distances were considered essential. These are possible in large Continental areas, but in the thickly populated United Kingdom it was difficult to find suitable sites. Our efforts were thus turned towards the graphite-moderated *gas-cooled* type of pile. In order to bring the blower power for circulating the coolant down to the lowest practicable level, it seemed necessary to operate the pile under pressure until it became apparent that it would be possible to operate at atmospheric pressure if sufficient flattening of the neutron distribution across the pile was done.

The British White Paper Plan

It is on the construction of reactors of the graphite-moderated gas-cooled type that the first stages of the British



reactors

program for the development of industrial power are based.

The first reactors which are at present being built may have shortcomings but they have the advantage of being inherently safe and capable of generating electricity in large quantities to a guaranteed program and at prices comparable with those of a modern conventional power station. They cannot stand on their own since the electricity cost is estimated at 0.76 pence/unit with a uranium cost of £20,000/ton. They are competitive only when there is a market for the by-product plutonium and this market must be found by recycling or by use in advanced types of reactors, culminating in the fast reactor.

The program starts with the construction of two gas-cooled graphite-moderated stations, each with two reactors, on which construction will begin about mid-1957 and operation to start in 1960-1961. The construction of two further stations would begin about eighteen months later in which the reactors would be of a similar type to those in the earlier stations, but they should show an improved performance particularly in heat rating. The total electrical output from these four stations, which should be in operation by 1963, should be between 400 and 800 mw. By 1960 four more stations should start construction followed by four more eighteen months later, and when they are all in operation by about 1965, the eight stations in this group should supply well over 1,000 mw. The first four of this group may well be developments of the gas-cooled graphite-moderated type and the last four may be of the liquid-cooled type which may then have been developed sufficiently to be economically satisfactory.

Calder Hall Piles

In the first (Windscale) piles which were built for Pu production, all the heat is wasted. When they were being built, a study of the graphite-moderated, pressurized gas-cooled pile from which power would be produced was continued, and in 1953 it was decided that it was reasonable and prudent to proceed with the construction of such piles at Calder Hall in Cumberland. In principle the pile is shown in Figure 1.

Induced draft air-cooling is supplied to the space between the thermal and the biological shield and the outlet air is exhausted 200 ft. above ground level from the two stacks on the pile building.

The mass of graphite moderator is contained in a cylindrically shaped pressure vessel. The machined graphite blocks have vertical uranium charge and control rod channels, the adoption of vertical channels simplifying the graphite structure and making the design of the coolant circuit more convenient.

The pressure vessel is of 2-in. welded steel plate and is about 40 ft. in diameter and approximately 60 ft. high. Fabrication was carried out on the site in five main sections. Each section was lowered through the pile vault roof, and the final welds being completed in situ. Butt welds were radiographed and all important fillet welds were examined by crack detection techniques. Stress relieving the completed vessel was achieved by radiant heating which required a peak electrical load of about 1½ mw. The vessel temperature was brought up to more than 550° C. and held there for 8 hr. before being allowed to cool slowly and evenly. The vessel was then pneumatically pressure tested. Hydraulic testing techniques would have overloaded the structure.

The final test was at 1/10 atm. pressure and was done by means of the large rotary vacuum pump which is part of the operational equipment required for exhausting the vessel when charging or changing the carbon dioxide coolant.

The reactor charge and discharge arrangements are accommodated on the pile vault roof along with the pile control and shut-off gear. The control rods and shut-off rods are made of stainless steel tube lined with boron steel fillers and are suspended through the roof of the pile.

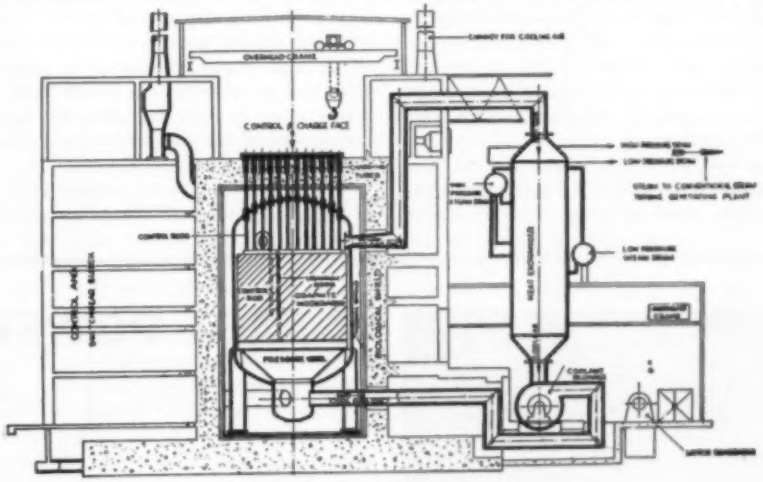


Fig. 1. A gas-cooled power reactor.

The hot *CO_2 coolant* is led away from the top of the pressure vessel by 4 ft., 6-in. diam. steel ducts to the four heat exchangers which are situated at the corners of the pile building. The cool CO_2 coolant from the base of each heat exchanger is boosted by four main blowers and returned to the inlet manifold at the base of the pressure vessel. Motorized isolating gate valves are included in each hot and cold duct and flow cascades are fitted at the bends in the ducts. The problem of accommodating the large thermal expansions between the pressure vessel and the heat exchangers is solved by the use of bellows.

The four CO_2 coolant blowers are of the single-stage centrifugal type with an overhung impeller. The overhung-impeller arrangement has the advantages of requiring only one gland and permitting arrangement of the gland and bearings so that access can be obtained without exposure to radiation which is above tolerance level.

Control of the mass flow of coolant is carried out by controlling speed of blower rotation. The 2,000 hp. d.-c. motors permit speed variation over range of 10:1. About 2% of the mass flow through each blower is taken from the downstream side of the blower, filtered, and reintroduced to the system on the upstream side of the blower to prevent accumulation of graphite and iron oxide dust in the coolant system. Dew point of the coolant is kept below the necessary limit by alumina.

Continuous monitoring of the coolant gas stream for the detection of burst fuel elements is also carried out.

More than 20 tons of carbon dioxide are required for the reactor and coolant circuits. Charging is carried out by exhausting the system and then admitting CO_2 which is generated from eight standard converters charged with blocks of solid carbon dioxide. Purging by repeated charging and discharging is necessary in the first filling.

Each of the four heat exchangers is contained in a vertical steel pressure shell of 3/32-in. steel plate; they are about 18 ft. diam. and some 70 ft. high. The 30,000 sq.ft. water heating surface

comprising high pressure and low pressure economizer, evaporator, and superheater sections is made of 2 in. over-all diam. mild steel tubing through which the water and the steam pass. The gas surface of the tubes is extended by the use of elliptical steel stud tube construction. Flow in the evaporator sections is by forced circulation from pumps maintaining a circulation rate of about four times the steam output of the section. Each evaporator has a single steam drum, 4 ft. diam. and 18 ft. long which contains conventional cyclones and scrubbers.

The dual-pressure steam system which is used obviously adds complexity in the design and operation of the station and was adopted only after careful consideration. The fixed point in the design is the temperature which can safely be achieved in the outgoing gas from the reacting core.

It is obviously desirable to make the inlet temperature of the gas entering the reactor as low as possible. This is done by adding cooling surface in the heat exchangers. But if an attempt is made to reduce the temperature of the coolant below a reasonable level, the heat abstracted will be of too low a grade to be used in the thermodynamic cycle for power production; the bottom slice of heat removed from the cooling gas will have to be rejected to drain.

Reactor rating can therefore be kept up by generating steam at a low pressure. However, it would not be economical to raise all the steam at a low pressure since by doing this the capital cost of the turboalternator would be increased and the thermodynamic efficiency would be reduced.

Future Developments for Power Production

It is shown in the White Paper published by the British Government in February, 1955, that when a reasonable allowance is made for the value of the plutonium produced as a by-product in graphite-moderated gas-cooled reactors, electric power can be generated from them at an all-in cost of 0.6 pence/unit sent out. This estimate of cost is based on the use of techniques which are at present known. With the development of better techniques, it should be possible to reduce the generating cost even further.

One of the limiting factors in the design of reactors of the Calder Hall type is the size of pressure vessel which can reasonably be constructed. If the volume of the pressure vessel is increased, then the total thermal capacity of the reactor also can be increased and the capital cost per kilowatt sent out is brought down. It is hoped that future developments will include the welding of thicker gauge plate, possibly up to 3 in., enabling the use of larger pressure vessels to become practical. Another line of approach is to use a spherical pressure vessel which, with a given plate thickness, could be made nearly twice the diameter of a cylindrical container.

The search for a better reactor coolant is continuous; one of the most suitable coolants is helium which besides being chemically stable has a high specific heat and offers a negligible capture cross section to thermal neutrons.

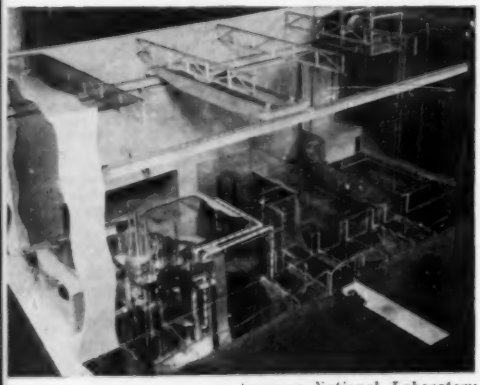
Carbon dioxide on the other hand is cheap and readily available and its neutron capture cross section is entirely satisfactory. In addition it is fairly stable chemically as it does not react with the graphite moderator to any important extent.

Nitrogen is not attractive; its circulation would absorb an unduly high proportion of the energy generated, and its neutron cross section is high.

Hydrogen offers interesting possibilities. First it would act as a moderator resulting in a reduction of graphite and structural costs while a loss of coolant would reduce the pile reactivity, thus giving great stability. Second it would only require about 1/10 of the blower power required for carbon dioxide. It reacts with uranium at certain temperatures however and this might cause serious trouble, because it can pass through the can by diffusion even while the can remains sound. Diffusion of the hydrogen into the structural steel of the reactor may also be a cause of trouble.

The use of a slightly enriched uranium charge may also lead to economies.

In the pure engineering field, there can be no doubt that the design of heat exchangers can be considerably improved and cheapened. The problem of raising steam by transferring heat to the water from a perfectly pure and clean gas has never before had to be considered on a large scale.



Argonne National Laboratory

Model of Argonne Experimental Breeder Reactor II. The reactor which uses enriched uranium as fuel and a liquid metal as a coolant, has both a primary and secondary liquid-metal system. Heat is conducted by the liquid metal from the reactor tank to the steam generator shown in the center. Steam, thus produced, is led to the turbogenerator at right, in which electric power will be produced.

FAST POWER REACTORS

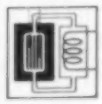
W. H. Zinn | Argonne National Laboratory, Chicago, Illinois

U.N.-A/Conf. 8/P/814

Increasing the utilization of the raw material always must be a prime objective of the nuclear energy technologist, just as it has been a traditional objective of the developers of coal-fired electric generating plants. It is clear that in the matter of our present utilization of raw material, nuclear technology is in an embryonic state.

The first measurements of the number of neutrons emitted per fission, made in 1939, raised the hope that there would be more neutrons available than just those required to maintain a chain-reacting system. Some years later, about 1944, measurements for uranium had been made with considerable precision. At that time, the question of breeding fissionable material from U^{238} and thorium began to receive serious attention.

Because U^{238} seems to be more than one half of the raw material resource available to the world, it is an important matter to devise reactor systems which potentially correct the unfavorable situation indicated by the *thermal* (slow) neutron values for the ratio of neutrons emitted per neutron absorbed. In order to capitalize on this situation, it is necessary to devise reactors which operate on neutron energies other than thermal, and there is some indication that the most favorable situation would be achieved if the average energy of the neutrons in the reactor is kept as high as the nonmoderating materials composing the reactor naturally permit.



reactors

Reactors meeting such objectives have been termed "fast" reactors.

In the United States, two reactors have been operated as fast reactors: one, constructed by Los Alamos Scientific Laboratory, was fueled with plutonium; the other, constructed by Argonne National Laboratory, is fueled with U^{235} enriched to at least 90%. Such operation with its net gain in fissionable fuel must experience losses because of fission product absorption, losses to the control system, or losses of fissionable fuel in chemical processing and in the fabrication of fuel elements. The frequency of carrying out these processing operations becomes a matter of first importance.

Radiation Damage

It is likely that radiation damage will be the effect which limits the exposure of fuel elements. Corrosion of structural metals in sodium is so small that no difficulty is anticipated in holding fuel elements at temperature for any required time.

Loss of reactivity may be a problem, even with internal breeding, but the advantage of obtaining high burn-up is so overwhelming in the over-all evaluation of the cycle that it is unlikely that loss of reactivity will be permitted to curtail fuel-element exposure. It is assumed that structures will be developed which will permit 2% of the fuel alloy to be fissioned before radiation damage forces the removal of the fuel for reprocessing.

Additional Losses and Plant Performance

The frequency of reprocessing of the fuel is determined by the allowable burn-up. Accepting that 2% of the atoms of the fuel alloy can be fissioned before radiation damage forces removal, the loss in breeding ratio due to fission product absorption can be estimated. In a single fuel cycle, 20% is fissioned. During the cycle, the fission-product concentration corresponds to the conversion to fission products of 10% Pu. For each plutonium atom fissioned, two fission-product atoms are created. A specific power of 1670 kw./kg. and a 2% burn-up lead to a residence time for the fuel in the reactor of 110 days. On the average, the whole core charge will be reprocessed after 110 days of exposure. If it is assumed that in the reprocessing and refabrication of the fuel elements a total loss of 0.5% fuel alloy is sustained/cycle, the effect on the breeding ratio can be estimated. The ratio of Pu lost to Pu fissioned/cycle is 0.025. Five cycles are required to fission all of the plutonium, so the fraction of plutonium lost becomes 0.125. The reduction in breeding ratio due to these losses is 0.105. The final breeding ratio for the reactor and reprocessing cycle, including losses to fission products, now becomes 1.58.

The interest rate is the quantity which best measures the breeding performance of a reactor system. It is the extra material generated per unit of fissionable material invested in the plant per unit time. With a 110-day operating cycle, the interest rate for the dilute breeder is seen to become 4.84×10^{-4}/day, and the investment of fissionable material in the plant will be doubled in 5.6 years.

Heat Transfer

The feasibility of obtaining the performance indicated is largely dependent upon the feasibility of obtaining the high heat transfer rates required by the high power density.

The power density in the fuel alloy is 3.17 kw./cc. The average heat flux for the surface of the fuel alloy is 68 cal./(sec.)/(sq.cm.). The thermal conductivity of the fuel alloy is a matter of considerable concern. The physical properties of plutonium alloys are not well determined, and particularly the thermal conductivity, when up to 2% of the material has been replaced by fission products, is not known.

Reprocessing of Fuel

The fast breeder reactor potentially makes its greatest contribution to the fissionable material economy when plutonium is cycled through it as the fuel. This requires the development of techniques for the removal of accumulated fission products from the fuel alloy and the refabrication of this material into fuel elements.

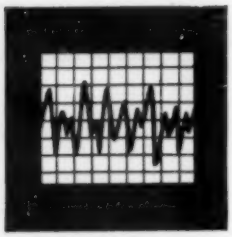
Decontamination of the fuel can be done by any of a number of processes. Solvent extraction is well demonstrated and the estimates of cost do not prohibit its use. Where the fuel alloy is to be recycled to the reactor, it is, of course, not necessary to separate plutonium from uranium. The fact that the recycled material will contain plutonium and therefore is intensely α radioactive makes the problem of fabricating the fuel elements one of great difficulty. The fabrication techniques must be of the simplest kind in order that they will be adaptable to the protective measures which must be taken. This fact suggests that it may not be necessary to provide for the very high degree of decontamination of the recycled material customarily given reactor materials. For at least some of the cycles of the reprocessing system, decontamination might be by means other than aqueous solution chemistry; especially pyrochemical processing, in which the fuel alloy is kept in its metallic state, may bring important savings in cost, mainly because the volume of material to be handled will be small and, consequently, the shielded equipment also will be small. In any case the development of fuel elements meeting both the heat transfer requirements of the fast reactor and the requirements of fabrication in the presence of plutonium presents a challenge to the uranium metallurgist and the engineer.

Fast and Thermal Systems Combined

Thermal reactor systems fueled with natural or slightly enriched uranium will require additions of fissionable fuel because the conversion ratio probably is less than 1. In the first instance, this will be done with U^{235} which is separated from freshly mined uranium. In the further development of the atomic energy power industry, the recycling of plutonium to reactors will be accomplished. It then would appear better to supply plutonium make-up for the thermal reactor system from a fast reactor system with a net production of plutonium rather than to separate U^{235} from newly mined uranium. Economic analyses based on the fuel value only of plutonium indicate that with a fairly high interest rate the income to the fast reactor system of the sale of plutonium is a sizable item. It would appear to be adequate to pay for the added expense involved in making fuel elements of extended cooling surface. By making use of fast breeder reactors in this manner, the thermal reactors and the breeder reactors operating together will be able to consume a sizable fraction of the mined U^{238}. This situation, of course, will not come about unless power production by fast and thermal systems are in balance. It appears that the development of thermal reactors for power production is proceeding on a scale considerably more rapid than that of the admittedly more difficult fast reactor development. This indicates that there will be a considerable time during which the usage of U^{238} will be very poor. Thermal reactors with long burn-up, however, can be a source of plutonium for the fast reactor. A number of thermal converters are under design whose fuel elements call for a type of construction which is not likely to be accomplished with alpha-active material. The plutonium remaining in the discarded fuel elements from such reactors should be a convenient and relatively inexpensive source of the hundred of kilograms of plutonium required by the fast reactor.

U.N.-A/Conf. 8/P/853

hazards and risks



THE SAFETY OF NUCLEAR REACTORS

C. Rogers McCullough
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Mark M. Mills
University of California Radiation Lab, Livermore

Edward Teller
Department of Physics, University of California

Reactor Technology

Along with a long list of possible attractive features of reactors, there are certain dangerous characteristics. The Advisory Committee on Reactor Safeguards (see page 450) has the responsibility of looking at the hazards connected with nuclear reactors. The members of this committee are exceedingly anxious to see rapid and fruitful development of reactor technology, but because of the nature of the hazards involved, and because they have been specifically requested to look at hazard problems, they feel that it is important that no undue or foolhardy risks be taken in the development of nuclear reactors.

Argonne National Laboratory

Reactor Safety

When one attempts to evaluate reactor hazards, there is the need for defining reactor safety, and what this will include. Absolute safety is not possible, but the minimization of hazards is possible until one has an acceptable calculated risk.

The operation of nuclear reactors appears safe and it is, in fact, deceptively safe. A nuclear reactor will not run away unless a number of serious mistakes of planning and operation should be committed. It is, however, impossible to conduct extensive operations over a long time without occasional occurrences of such mistakes. We have been exceedingly lucky so far that nobody has as yet been killed by a runaway reactor. It is not possible to count on an indefinite continuation of such good luck. The real danger occurs when a false sense of security causes a relaxation of caution.

One of the current difficulties in evaluating reactor hazards is this lack of experience with reactor accidents. For this reason, statistical information about reactor accidents, although all favorable, does not suffice to give useful statistical information of the type needed by insurance companies, for example, in evaluating the nature of hazards. To determine what is an acceptable risk, a certain amount of judgment, detailed technical evaluation of a given reactor, and caution must be employed.

Problems of reliability, adequate control, adequate supervision must all be included. It is convenient to look upon the concepts of reactor safety in the following ways:

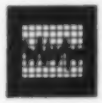
One important concept is the division of safety problems into on-site and off-site problems. The on-site problems have to do with the protection of reactor operating personnel and other people who may be at the reactor site in order to make use of it, and the protection of the economic investment in the reactor facility. Off-site problems concern the protection of the general public, or persons who are not more or less directly connected with the operation of the reactor.

For off-site people who have no knowledge or interest in the operation of the reactor, it seems that prevention of danger to their persons or damage to their property is a mandatory moral obligation in the operation of a reactor. This problem is more severe than in the case of dangerous chemical or explosive plants, because the radioactivity contained in a reactor can constitute a hazard to a wide area if it escapes from a machine and becomes dispersed. This public hazard has been one of the main concerns of the Advisory Committee on Reactor Safeguards.

From another point of view, the safety of a nuclear reactor can be said to depend upon two things: The *intrinsic built-in stability and reliability* of the machine, and *administrative control of the machine and its operation.* For example, the reactivity may decrease rapidly with increasing temperature. In this case, it may be practically impossible to exceed some safe limit in temperature. One would like to minimize the dependence upon administrative control for safe operation of a reactor. However, as a matter of practical fact, most reactors will nearly always require a certain dependence upon administrative control for safe and reliable operation. This means that problems arise connected with the loading and unloading of fuel, the start-up and shutdown of the reactor, proper manipulation of controls, and adequate accounting for all materials made radioactive by the reactor, including both intentionally irradiated material and any radioactive effluent associated with the operation.

Contained Radioactivity

The most serious continuing hazard associated with nuclear reactors is due to the large amount of radioactivity which they contain. Large reactors may contain hundreds of pounds of radioactive fission products which correspond to many tons of radium in conventional radioactive measure. Not all of these fission products are as hazardous as radium, but nearly all of them contribute substantially to the hazard. *There are two ways* in which this hazard may be minimized: one is to remove fission products during the operation of the reactor in such a way as to maintain a minimum concentration of such material in the machine. This continuous removal of fission products requires some type of fluid fuel, either liquid or gaseous, in order to continue clean-up operations on the fuel during the operation of the machine. *The second way* is to minimize the possibility of the escape of these fission products from the machine. The potential ability of a reactor to run away may make it possible for this radioactive material to escape to the surrounding areas. The hazard is crudely analogous to conducting both explosive and virulent poison production under the same roof.



hazards and risks

Until really safe nuclear machines of the future become available, we have to construct our reactors with extreme circumspection and we must continue to operate them with the same caution after ten years of safe running as on the very first day when they were started up.

In order to emphasize the characteristic of the special hazard due to radioactive materials in the reactor, a list of tolerances is presented in Table 1. It is evident that radioactive poisons are more hazardous than chemical poisons by a factor of something like 10^6 to 10^9.

In Table 2 there is a summary of delayed heat production and the corresponding radioactivity from fission products. For a 250,000 kw.-heat power (60,000-kw. electric power) machine, something like 300 million curies of activity remain at the end of one day after shutdown. This corresponds to 300 tons of radium in terms of radioactivity. The sheer quantity of radioactivity is enormous.

Operation of this reactor for one year produces about 100 kg. fission products. On the basis of 10^{-7} mg./cc. this can contaminate 10^6 cu. km. air to tolerance. Stated another way, a layer of air one km. deep covering an area 1,000 km. on a side could be brought to tolerance level.

Another feature of radioactive poisons is that a lethal level is not detectable by human senses. Furthermore, serious injury may not be detected for some years after exposure.

Escape of Radioactivity

The way in which reactors can malfunction and lead to the escape of fission products may be classified as follows: (1) a supercritical nuclear excursion or nuclear runaway, (2) meltdown of reactor components, even with the chain reaction shut down because of the delayed heat produced by the radioactive fission products, and (3) possible exothermic chemical reactions among the components of the reactor itself. The latter, although it is clearly not present if the machine is operating normally, may be initiated by a runaway nuclear chain reaction or by delayed heat melting. Indeed, for certain types of reactor structures, it would appear that the chemical reaction that might follow a nuclear runaway would produce substantially greater energy and violence than the runaway which preceded it.

The first two are unique to nuclear reactors compared to other power sources, and have no true analogue in other areas of technology.

The Problem of Nuclear Runaway

Nuclear reactors have a potential ability to achieve extremely high-power levels in a short time if adequate control of the machine is lost. A typical nuclear runaway accident may start and be over in appreciably less than a second. In this respect they are different from any other large-scale machines, and it is this extremely short time that makes it quite important that automatic control and safety systems be available, reliable, and relatively rapid in their operation.

Another feature of a possible nuclear runaway is that it does not seem to be very violent. Even though rapid in terms of human reaction times and conventional external emergency human actions, a nuclear reactor is a sluggish device and does not produce a nuclear explosion even remotely approximating that of an atomic bomb. For the large thermal reactors, nothing like an explosion really occurs. For very fast reactors with a nonthermal neutron spectrum and heavily loaded with enriched uranium, it does appear possible to have an accident which is fast enough so that portions of the machine may be propelled with velocities of a few meters per sec., similar to events that might occur in an automobile accident. Therefore, a nuclear runaway, in itself, does not represent a serious hazard to off-site people.

The Safeguard Committee has urged the development of *automatic fuses* which would have *two characteristics*. They should be self-contained and wholly automatic so that they are not subject to error of adjustment or maintenance and are not subject to intentional tampering. The fuses are also to be activated by changes in the power level, essentially changes in the flux level of the nuclear reactor, and have rapid enough response so that they will introduce a substantial negative reactivity in the reactor in a time of the order of one second or less. It appears that development of such a fuse will soon be achieved, but because of the short-time requirement it will be neither easy nor simple.

What are the *characteristics of a nuclear runaway*, assuming that it is actually underway? *First* excess reactivity is inserted; the reactor then rises exponentially in power level until enough energy is accumulated in the structure to affect the behavior of neutrons.

A final phase of the runaway will occur when enough of the reactor structure is actually melted, vaporized or otherwise affected (only in some cases will reactivity coefficients be adequate to shut the reactor down without destructive effects), and these destructive effects will shut down the nuclear chain reaction and stop the nuclear runaway.

In many reactors, the heating of the moderator will beneficially reduce reactivity. However, the time for heating may be sufficiently long, that it does not have time to come into play during a nuclear runaway. For example, the thermal diffusion time across a 4-in. thickness of graphite-moderator in a large lumped thermal machine is nearly a minute.

One of the important technical areas associated with understanding nuclear runaway behavior of a reactor is that of heat transfer under transient conditions. Relatively little knowledge in this area has been available because most heat transfer studies are conducted under steady-state conditions.

How fast the escape of nuclear runaway fission products will be depends upon the type of reactor and type of reactor accident. It may be possible to show that there will be little mechanical violence outside the reactor shield, so that if the building which houses the reactor can be made gastight, then escape of fission products to areas outside the reactor building can be greatly reduced.

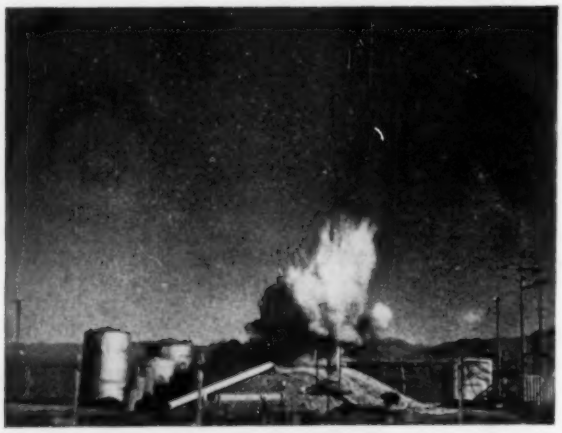
Delayed Energy Production

Nuclear reactors have another somewhat unfavorable characteristic. Because of the accumulated fission products and the accompanying exothermic radioactive transformation of these fission products, a nuclear reactor will continue to produce heat even when the nuclear chain reaction is shut down. For about one second after the reactor is shut down the delayed power level is approximately 7% of the normal power level.

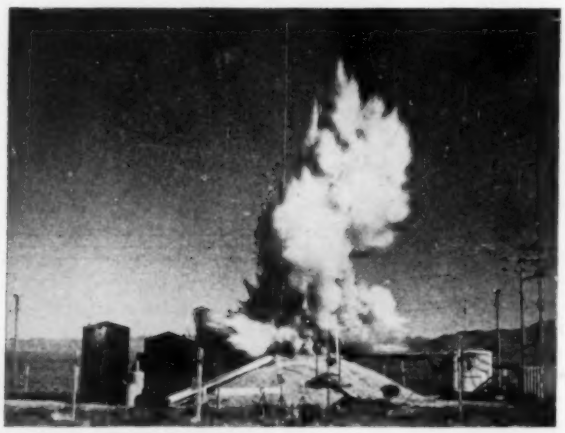
The delayed heat problem is clearly a serious one. If some failure in the cooling system should occur, breakdown of pumps, loss of pumping power, mechanical failure of cooling piping, then even if the nuclear chain reaction is immediately shut down by inserting control or safety rods, there will still be left a substantial heat load which must somehow be disposed of.

For example, if the fuel elements from the Materials Testing Reactor were suddenly removed from the reactor and left standing in the open air, they would melt down by themselves by delayed heat production. If they were suddenly

Shown is Argonne National Laboratory's Borax I reactor facility prior to its final operation on July 22, 1954. The reactor had been constructed in the summer of 1953 and had been used in a series of experiments in 1953 and 1954 to determine the characteristics of a water-cooled, water-moderated reactor when operating under boiling conditions. At the conclusion of these tests, the reactor was subjected to one single final test in which the power was increased to more than ten million kilowatts in a tenth of a second.



Almost simultaneously with the removal of the control rod from the reactor, a dark-grey colored column was ejected from the reactor to a height of more than 80 ft. Shortly thereafter, the sound of a medium sharp detonation reached the control trailer which was located one-half mile away. Just prior to the appearance of the ejected material above the upper edge of the shield tank, a flash of light from the tank could be seen and was recorded by the high-speed cameras. This flash lasted about 3/1000 of a second (0.003 sec.) and was extinguished before the first bit of water appeared above the earth shield.



A portion of the rectangular box which housed the control equipment may be seen directly above the center portion of the earth shield. The light-colored objects are believed to be fragments of the uranium-aluminum fuel plates which are burning in the air.

This photograph, made at the height of the explosion by a high-speed camera, shows a large amount of debris in the air. Portions of the reactor tank, control rod mechanism, and reactor core have been hurled 80 ft. into the air. Most of the fuel element fragments fell to earth within a radius of 200 ft. around the reactor. There was no dangerous fall-out at distances greater than a few hundred feet.

Photographs on this page are scenes from a motion picture record of the experiment. Courtesy Argonne National Laboratory.

immersed in water, probably this melting would not take place. One concludes that this temperature rise, although not so rapid as to constitute a sudden event in terms of human reaction times, is nevertheless rapid enough to be quite troublesome. In Table 2 some delayed heat power levels are summarized.

Three types of preventive designs are suggested. One is to have a stand-by emergency cooling system which works either by gravity flow of coolant or by natural convection. Another is to have stand-by emergency arrangements of some sort which might be rather analogous to fire-fighting equipment. The "fire-fighters" would then approach the reactor and make suitable connections and force through emergency cooling. A third possibility is to have stand-by forced convection cooling similar to the main cooling system but connected to a special power supply and with special separate piping.

It is clear that a delayed accident, if it could not be brought under control, might very well lead to sufficient disruption of the reactor core to allow fission products to escape. It is also clear that this again will not be of itself a violent event, and it is probable that an accident of this kind can be minimized by providing a gastight building around the reactor.

Chemical Reactions

Exothermic chemical reactions may result from melting and mixing of reactor components. A simple example of this type is that of an air-cooled graphite reactor. A sudden temperature rise in the uranium fuel may be sufficient to cause it to melt and heat the adjacent graphite so that both the uranium and graphite can burn in the cooling air. If the air supply is not turned off, it is likely that a substantial portion of the reactor could be consumed in this way. This would then disperse radioactive fission products into the surrounding area through the exhaust portion of the cooling system.

Another example is that of a heavy-water-moderated and cooled natural uranium reactor. In a machine of this sort a runaway accident could melt the uranium and allow it to mix intimately with the water. In this case the thermodynamic potential indicates that an exothermic chemical reaction can take place. Whether or not such a reaction would be rapid and violent is not clearly known.

If an exothermic reaction of this type goes to completion, the resulting energy release will nearly always be substantially greater than the energy generated in a preceding nuclear runaway. Thus it is important to determine the possible chemical reactions. A substantial increase in reactor safety can be achieved

by the elimination of possible reacting components in the reactor structure.

Safe Designs

It seems worth while to summarize the preceding discussion with a few remarks concerning the approach to safe reactor designs. It is desirable to provide a large negative reactivity coefficient.

The control system must be carefully designed so that in the event of too high a power level, too high a rate of rise of power level, a serious reduction in coolant flow, or any major failure of fuel elements, the reactor will shut down in a time interval small enough to minimize damage. All potentially dangerous failures should be monitored by instruments and control channels leading to shutdown or "scram." These monitors and channels should be at least in duplicate, independent of each other, and preferably of different types. In addition, care should be taken that a failure cannot put the controls out of operation.

Administrative Control

Although good administrative control of the reactor does not lead to the same degree of confidence in the good behavior of the machine that intrinsic gremlin-free, built-in stability does, nevertheless, good administrative control does enhance the safety and reliability of reactor operation. Indeed, good administrative control is mandatory for those people who have an economic stake in the reactor. From the point of view of public hazard, careful reactor operation and maintenance make it much less likely that there will be a reactor accident.

However, this administrative control should not start just when the reactor is put into operation. Throughout the design and construction of the reactor thorough supervision, careful design for reliability, and thorough testing of all reactor components including coolant system, off-gas systems, shims, safety and control mechanisms, and all control and operating instrumentation should be carried through. All these components should be given systematic and thorough shakedown testing before the reactor is put into operation and before it becomes radioactive so that modification, correction, and maintenance can be done with less difficulty. Indeed, it is extremely difficult to emphasize how important it is to have complete, thorough, systematic shakedown of all portions of reactor control and instrumentation.

In the design of the reactor attention should be given to the problem of maintenance after reactor is placed in operation. It should be possible to enter all instrument areas, most of the control areas, and obviously the central control room after the machine has started up and been operating for some time. Fuel-element failure, a continuing problem, may allow radioactivity to enter portions of the reactor structure which normally would be expected to be radiation-free. This should be taken into account in the original design.

Table 1.—Comparison of Toxic Substances in Air†

Substance	Concentration in mg./cu.m. Tolerance *	Fatal Dose**	Ratio Fatal to Tolerance
Chemical Poisons			
Chlorine	2.9	290	100
Arsine	0.16	800	5,000
Beryllium	1.5×10^{-5}	?	?
Radioactive Poisons			
U^{235} (insol.)	$1,690 \times 10^{-9}$	$1,690 \times 10^{-5}$	10,000
Pu^{239}	32×10^{-9}	32×10^{-5}	10,000
Sr^{90}	1.3×10^{-9}	1.3×10^{-5}	10,000

† It should be remembered that industrial poisons are usually in many ton quantities, whereas radioactive poisons are in 100-kg. quantities.

* Tolerance for chemical poisons is defined as the maximum tolerable level for 8 hr./day exposure. In the case of radioactive poisons tolerance is the maximum level which can be tolerated every day for 8 hr. equivalent to 0.043 roentgen equivalent, man (rem)/day.

** Fatal Dose in the case of chemical poisons is defined as the rapidly fatal dose when the given concentration in air is inhaled for 30 min. to 1 hr. In the case of radioactive material this means about 50% survival if the dose is acquired quite rapidly, for example, over a minute or perhaps during an 8-hr. day. This is equivalent to about 400 rem.

Table 2.—Delayed Heat and Power Radioactivity * after normal shutdown

Time after shutdown		Activity level from a previous steady heat power: 300 kw. activity as: kw.	300 kw. activity as: curies	250,000 kw. activity as: kw.	250,000 kw. activity as: curies
Sec.					
10	10 sec.	12.9	2.1×10^6	11,000	1.8×10^9
10^2	1.7 min.	8.0	1.3×10^6	6,800	1.1×10^9
10^3	16.7 min.	5.2	8.4×10^5	4,300	7.0×10^8
10^4	2.8 hr.	3.3	5.3×10^5	2,700	4.4×10^8
10^5	28 hr.	2.0	3.3×10^5	1,700	2.8×10^8

* The radioactivity figures are for fission products only (do not include radioactive fuels or components. It is assumed that the mean decay event corresponds to 1.0 Mev in converting from kw. to curies.

Once the reactor is placed into operation, continuing close supervision is essential. Maintenance procedures should be carefully followed and maintenance checks should be scheduled in an appropriate way. The period of reactor start-up is a particularly critical one, and should be followed very closely. Reactor loading and unloading are delicate operations, particularly the unloading of now-radioactive fuel elements. Start-up of a reloaded reactor must be carefully considered since the reactivity may have been affected by a new fuel loading. The normal, or routine, day-to-day operation requires close supervision so that troubles may be detected at an early date and corrective measures taken. Clearly, careless operation of the controls may lead to a supercriticality accident and the manipulation of the controls should be carried out only by people thoroughly familiar with the characteristics of the reactor and its associated equipment.

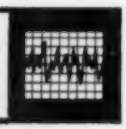
If a reactor is employed as an irradiation facility, it is possible for experiments to give rise to sudden changes of reactivity. Experiments should be planned, the plan reviewed by the administrative staff, and suitable emergency procedures decided upon before inserting experiments into the reactor.

Finally, there is one phase of the administratively controlled reactor which is usually taken for granted but may require a word or so: the careful accounting for all materials which have been irradiated in the machine. There is available usually a number of test holes in which experimental irradiations may be carried out. The samples so ir-

Chemical Processing Flowsheets

The choice of the organic solvent de-

hazards and risks



radiated can be highly radioactive and should not be allowed to accumulate unduly, or to be lost, or to be handled in an irresponsible manner.

Consequences of an Accident

The following discussion outlines the main features which can make a nuclear incident dangerous. In the event of a reactor accident, there will result probably a release of radioactive material from the reactor. Operating personnel may be seriously injured or perhaps even killed. The reactor itself may be damaged beyond repair or recovery. The reactor building and its associated equipment are likely to be heavily contaminated and indeed, it may not be possible to clean up the building sufficiently to put it into operation again. Design of the building so that possible clean-up operations are as easy as possible is desirable. Smooth, clean surfaces, perhaps clad in stainless steel, would make clean-up operations easier. Finally, radioactive materials can escape from the reactor site altogether. Fission products may be carried in the wind and spread over adjacent populated areas and constitute an acute hazard. Radioactive material may escape into the ground and be carried by the percolating ground water to adjacent rivers or other water supplies. Although a great deal needs to be known about the character of radioactive material that might escape from a reactor, whether it is in large or small particles, whether it is indeed gaseous, whether it would rise high into the air or seep slowly along and into the ground, nevertheless, some notion of the possible spread of the hazard could be obtained by a study of the meteorology, and hydrology at the reactor site. It is desirable, for example, to have the prevailing wind blow from the reactor to uninhabited areas. It is also desirable not to have the reactor site located on a main watershed. From the point of view of the hazard alone, it is of course desirable to have the reactor site far from populous or vital industrial areas. It will not always be possible to obtain this remote location and still obtain economic utility from the reactor. For this reason, the Safeguard Committee is continuing to emphasize the importance of safe reactor designs, the development of contained fuses to minimize the possibility of a runaway accident, and the use of gas-tight containing vessels and buildings.

Perhaps it is important again to emphasize the degree of public hazard that might follow a reactor accident. Assuming that good luck prevails and no one is killed, it may nevertheless be necessary to evacuate a large city, to abandon a major watershed, and probably it would be necessary to make the reactor site itself a forbidden area for some years to come.

Despite all these possible dire consequences, it is the belief of the Advisory Committee on Reactor Safeguards that nuclear reactors will soon start to produce substantially increasing material benefits to humanity. We believe that useful electric power in large quantities can be generated by nuclear reactors. It is our concern that rapid progress shall be made but that enough caution should be observed such that no catastrophic event will delay the fruition of reactor development.

THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS TO THE UNITED STATES ATOMIC ENERGY COMMISSION

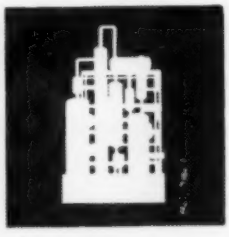
The Advisory Committee on Reactor Safeguards was formed by combining the Reactor Safeguard Committee and the Industrial Committee on Reactor Location Problems. At this time members are:

M. Benedict, Massachusetts Institute of Technology
H. Brooks, Harvard University
W. P. Conner, Jr., Hercules Powder Company
R. L. Doan, Phillips Petroleum Company
H. Friedell, Western Reserve University
I. B. Johns, Monsanto Chemical Company
C. R. McCullough, Chairman, ACRS
M. M. Mills, University of California Radiation Laboratory
K. R. Osborn, Allied Chemical and Dye Corporation
D. A. Rogers, Allied Chemical and Dye Corporation
C. R. Russell, Secretary, ACRS
R. C. Stratton, Travelers Insurance Company
E. Teller, Department of Physics, University of California
H. Wexler, United States Weather Bureau
A. Wolman, The Johns Hopkins University

The Reactor Safeguard Committee was formed in 1947, and the Industrial Committee on Reactor Location Problems was formed in 1949. The following were also associated with these committees for prolonged periods:

J. Dunford, United States Atomic Energy Commission
B. Holzman, United States Air Force
J. Kennedy, Washington University, St. Louis
F. Seitz, University of Illinois
G. Weil, formerly, Division of Reactor Development, United States Atomic Energy Commission
J. A. Wheeler, Princeton University

fission-product separation



REPROCESSING OF FUEL AND BLANKET MATERIALS BY SOLVENT EXTRACTION

F. L. Culler | Oak Ridge National Laboratory, Oak Ridge, Tennessee

and Others

U.N.-A/Conf. 8/P/822

With regard to a survey of the reprocessing technology of irradiated reactor fuel elements by solvent extraction, probably the most useful information that can be presented is the chemical flowsheets for solvent-extraction processes with a cursory discussion of the most important chemical and engineering process variables.

Those parts of the paper, condensed for this issue of C.E.P., are divided into three major sections.

1. Chemical Processing Flowsheets—a presentation of chemical flowsheets for reprocessing fissionable and fertile materials by solvent extraction.
2. Auxiliary Processes—a discussion of supporting processes, such as solvent recovery, iodine removal, and isolation procedures for fissionable products.
3. Equipment and Engineering Concepts—a review of the types of contactors that have been used for solvent extraction; a general discussion of design of radiochemical processing facilities covering maintenance philosophies and waste disposal; a listing of the relative costs of functional areas of a typical radiochemical processing plant.

column the plutonium is stripped from

ery of plutonium from irradiated natural

For the recovery of uranium from

Chemical Processing Flowsheets

Solvent-extraction processes have been developed for the following purposes:

1. separation of plutonium from natural uranium
2. separation of enriched uranium from aluminum and other diluents and cladding materials
3. separation of U^{233}, protactinium, and thorium

Solvent-extraction technology has progressed to the point where these fissionable and fertile materials can be separated from one another, from fission products, and from inactive diluents and contaminants. Nitric acid is a reasonable dissolution agent. For materials such as stainless steel and zirconium which are nitric acid insoluble, other mineral acids may be used for the primary dissolution; before solvent extraction is performed, however, the nitrate ion can be added either as nitric acid or as a salt such as aluminum nitrate to make the extraction take place from a nitrate system.

The choice of the organic solvent depends upon the selectivity of the solvent for the desired products, the ease with which products can be stripped from the organic material after the primary extraction, chemical and radiation stability of the solvent, immiscibility of the organic-aqueous mixture, specific gravity of the organic compared with the aqueous streams, interfacial tension, recoverability, viscosity, toxicity, flammability, and cost. Many organic solvents are suitable in the solvent extraction of fissionable and fertile materials. Some of the solvent systems that have been investigated are listed in Table 1. Around them and aqueous nitrate systems have been developed the processes listed in Table 2.

REDOX PROCESS

Both uranium and plutonium are extracted by hexone from concentrated aqueous nitrate solutions, whereas fission products are only slightly extracted. At the low acidities required for solvent stability and best decontamination, Pu(IV) may hydrolyze to the nonextractable polymeric form, and in addition is not extracted as well as Pu(VI); extraction of plutonium is therefore preceded by oxidation of plutonium to the VI state with sodium dichromate at elevated temperatures.

The Redox process is a three-column cycle in which plutonium and uranium are separated from each other and from the bulk of the fission products. The feed solution is acid-deficient uranyl nitrate containing sodium dichromate to oxidize the plutonium. Both uranium and plutonium are extracted with acidified hexone, and the organic extract is scrubbed in the same column with acid-deficient aluminum nitrate. In a second

Table 1.—Extractants for Solvent Extraction Processes

Solvent	Alternate Name	Diluent	Used to Separate	Salting Agent
Ethyl ether	Diethyl ether	None	U from ores	$Ca(NO_3)_2$, $Mg(NO_3)_2$
Hexone	Methylisobutyl ketone	None	U, Pu from fission products	$Al(NO_3)_3$
TBP	Tri-n-butyl phosphate	Kerosene fraction	U, Pu and Th from fission products and U and Th from ores	HNO_3
Carbitol	Dibutyl ether of ethyleneglycol	None	U, Pu from fission products	HNO_3
Pentaether	Dibutyl ether or tetraethyleneglycol	None or butyl ether	U, Pu from fission products	HNO_3
Trigly	Triglycol dichloride	None	U, Pu from fission products	$Al(NO_3)_3$
TTA	Thenoyl trifluoroacetone	Benzene	Pu from fission products	None
DIPC	Diisopropyl carbinol	None	U from fission products	None
OPPA	Dioctyl pyrophosphoric acid	Kerosene fraction	U recovery from ores	None
Cellosolve	Ethyleneglycol monobutyl ether	None	U from fission products	$Al(NO_3)_3$
DIPE	Diisopropyl ether	None	U from fission products	$Al(NO_3)_3$

Table 2.—Processes for Chemical Separation of Fissionable and Fertile Materials

Process	Organic Solvent	Aqueous Solvent	Irradiated Metal Feed	Salting Agent
		For Separation and Decontamination of U and Pu		
Redox	Hexone	HNO_3	Natural U, Al can	$Al(NO_3)_3$
Metal recovery	12.5% TBP in hydrocarbon	HNO_3	Caustic precipitated U, fission products	HNO_3
Purex	30% TBP in hydrocarbon	HNO_3	Natural U, Al can	HNO_3
TTA chelation	0.25 M TTA in hexone	HNO_3	Natural U, Al can	$Al(NO_3)_3$
		For Separation and Decontamination of Enriched U and Al		
25	Hexone	HNO_3, $Hg(NO_3)_2$ catalyst	U-Al alloy	$Al(NO_3)_3$
25, TBP	5% TBP in hydrocarbon	HNO_3, $Hg(NO_3)_2$ catalyst	U-Al alloy	HNO_3—$Al(NO_3)_3$
		For Separation of U^{233}, Pa, and Th		
Interim-23, hexone	Hexone	HNO_3, F^- catalyst	Th, Al can	$Al(NO_3)_3$, HNO_3
Interim-23, TBP	1.5% TBP in hydrocarbon	HNO_3, $F^- + Hg^{++}$ catalyst	Th, Al can	$Al(NO_3)_3$, HNO_3
Thorex	42.5% TBP in hydrocarbon	HNO_3, $F^- + Hg^{++}$ catalyst	Th, Al can	$Al(NO_3)_3$, HNO_3

stripped organic is reconditioned for subsequent reuse in the process.

dioxide by the combined effect of heat

column the plutonium is stripped from the organic by reducing plutonium to the inextractable III state without affecting the uranium. To prevent uranium stripping, the reducing solution contains aluminum nitrate and it is scrubbed with additional solvent before leaving the column. The uranium is then stripped from the organic phase in a third column by dilute nitric acid.

From the first cycle the uranium product is evaporated and put through second and third uranium cycles. The scrub solutions may contain a reducing agent to provide additional separation from plutonium.

The plutonium product from the first cycle, already salted with aluminum nitrate, is oxidized with dichromate and then decontaminated by additional solvent extraction cycles. The plutonium is extracted with acidified hexone and scrubbed with oxidized acid-deficient aluminum nitrate in one column and stripped with dilute nitric acid in a second column. A reducing agent is not required in the scrub stream, as in the first cycle partitioning column, where separation from uranium is accomplished. The plutonium solution from the strip column of the second cycle is then salted with $Al(NO_3)_3$ and put through a third cycle similar to the second. Waste volumes can be decreased by using the aqueous waste solutions from the second and third cycles in making up scrub solution for the earlier cycles.

A simplified Redox flowsheet is given in Figure 1. Decontamination factors that have been demonstrated for two cycles of the Redox process are given in Table 3.

Table 3.—Redox Decontamination Factors

	log D.F.					
	1st Cycle		2nd Cycle		Over-all 2 Cycles	
Constituent	U	Pu	U	Pu	U	Pu
Gross γ	3.7	3.9	1.8	2.9	6.5	7.7
Gross β	3.9	4.3	1.8	2.9	6.0	7.5

Table 4.—TBP Metal Recovery Decontamination Factors

Constituent	log D.F. one cycle	Constituent	log D.F. one cycle
Gross γ	4.7	Total rare earths	5.3
Gross β	4.4	Pu	2.5

TBP METAL RECOVERY PROCESS

Precipitation processes for the recovery of plutonium from irradiated natural uranium have been developed which do not recover decontaminated uranium from fission-product wastes. The uranium- and fission-product raffinates from such a process must be stored; this is done best after the wastes are neutralized with sodium carbonate and sodium hydroxide. Uranium can be decontaminated from fission products by solvent extraction with tri-*n*-butyl phosphate (TBP) in a process similar to the Purex process with the omission of the partitioning column. Any traces of plutonium which remain in the feed go into the first cycle aqueous waste; the extraction column is operated under reducing conditions, maintained by a reducing agent in the scrub, so that plutonium is not extracted.

The waste solution containing solids can be removed from the waste storage tanks as a slurry, concentrated by evaporation, and dissolved in nitric acid. The resulting solution is concentrated further and centrifuged to remove the remaining insolubles which are returned to waste storage. The solution that is solvent-extracted contains nitric acid, sodium nitrate, and some sulfate and phosphate ions, along with uranium. Although sulfate and phosphate interfere with uranium extraction under some conditions, the nitrate concentration in the feed can be made sufficiently high to prevent serious interference with uranium extraction. The solution is extracted with tributyl phosphate in hydrocarbon diluent, and is scrubbed with a solution of nitric acid and a suitable reducing agent. The extract is then contacted with dilute nitric acid to strip the uranium into the aqueous phase. Uranyl nitrate product is finally concentrated by evaporation and possibly denitrated if uranium oxide is a desired product.

For the recovery of uranium from wastes which have decayed for two years or longer, one cycle of decontamination is sufficient. After shorter decay, additional cycles may be required.

A flowsheet for the TBP metal-recovery process is not included, since it is very similar to that of the Purex process. Decontamination factors attainable are given in Table 4.

Product uranium has 30-90% of the activity of natural uranium in secular equilibrium with its decay products. These data are valid for uranium solution that has decayed longer than two years, and from which plutonium has been removed by a process which recovers plutonium only.

THE PUREX PROCESS

Jacketed uranium metal is charged into a dissolver where the customary aluminum sheath is preferentially dissolved by a sodium hydroxide-sodium nitrate solution. The uranium is then dissolved in nitric acid. The concentrated uranyl nitrate-nitric acid solution is withdrawn, filtered to remove silica and aluminum particles, and adjusted to the feed concentration. Finally, the plutonium is quantitatively stabilized to the tetravalent state, the form most readily extracted by TBP, and the feed is ready for solvent extraction. Batch or continuous dissolution of uranium metal can be used.

The metal feed is extracted with TBP diluted with a kerosene-type carrier. Here conditions of flow and salting strength are regulated in such a manner that the uranium and the Pu(IV) are coextracted almost quantitatively, leaving most of the fission products and other impurities in the aqueous phase. Under these conditions some fission products are also extracted, but these are partially backwashed into a nitric acid stream flowing countercurrently to the solvent stream. The bulk of the radioactive and nonradioactive impurities leave as an aqueous waste stream, and the organic product stream is passed into a second contactor for uranium-plutonium partitioning.

In the second contactor uranium and plutonium are separated by reducing the latter to the highly aqueous-soluble trivalent state. Salting strength and flow conditions are controlled in such a manner that separation of the two products is virtually complete, the aqueous plutonium stream leaving the lower end of the column while the uranium remains in the organic phase.

The uranium-bearing organic solvent is passed into the bottom of a third column, where the uranium is stripped from the organic with water. The

stripped organic is reconditioned for subsequent reuse in the process.

The dilute plutonium stream flows directly to the second cycle for continuous feed make-up, in which the salting strength is raised by addition of nitric acid and the Pu(III) is oxidized to Pu(IV). The plutonium is extracted by the solvent to complete its separation from residual activity. The organic product stream flows into a second contactor where the plutonium is again reduced to the trivalent form and is stripped into an aqueous hydroxylamine sulfate solution. At this point, the product stream is concentrated by absorption on and elution from a cation-exchange resin bed. Additional purification is realized from this step such that the over-all separation of plutonium from fission products can exceed 10^7.

The aqueous uranium stream from the first cycle flows to a continuous evaporator and is concentrated and then adjusted with nitric acid. Following this the uranium is extracted and is scrubbed in a manner similar to that of the first-cycle extraction. The extracted uranium is stripped into water in a second column and is concentrated in a second evaporator. The concentrate is passed through a bed of silica gel which adsorbs trace fission products to complete the removal of fission-product activity. The uranyl nitrate concentrate then is calcined to uranium trioxide.

Since the solvent is reused, it is sent to a solvent-recovery area after each pass through the system, where it is washed with a sodium carbonate solution and then with dilute acid, to remove the traces of strongly complexed radioelements and the TBP degradation products. Over-all solvent losses can be maintained as low as 0.01%.

The aqueous wastes from the solvent-extraction cycles are concentrated, and nitric acid is simultaneously distilled and recovered. Other nitric acid is recoverable from the slug dissolution and denitration operation so that nearly all the acid employed in the process is available for reuse. The main incentive, however, for acid recovery is the reduction in volume of active wastes, which must be stored indefinitely.

For feeds containing large concentrations of fission products (i.e., those which result from high reactor burn-up and/or short decay periods), an additional cycle of extraction on both the uranium and the plutonium streams may be required. In addition, a feed oxidation and filtration step may be added prior to the preparation of first-cycle feed. This treatment is carried out by adding potassium permanganate to the feed solution, warming and centrifuging off the resulting manganese dioxide. The permanganate is reduced to manganese dioxide by the combined effect of heat and radiation. Plutonium is oxidized by both permanganate and manganese dioxide to Pu(VI), which is not adsorbed on manganese dioxide. The small amount of uranium and plutonium occluded by the precipitate is washed out with dilute nitric acid and recycled to the next batch of dissolver solution. The manganese dioxide centrifuge cake is subject to further reduction to manganous ion under the action of intense radiation. Feed preparation is completed by adding nitrite, which reduces Pu(VI) back to Pu(IV), and by adjusting the uranium and acid concentrations to the specified values. The precipitation of manganese dioxide scavenges traces of solids from the solution.

A schematic chemical flowsheet for the Purex process is shown in Figures 2, 3, and 4.

Attainable decontamination factors after solvent extraction of U and Pu through two cycles of solvent extraction are given in Table 5; additional decontamination for uranium after silica-gel adsorption and for plutonium after ion exchange also are shown.

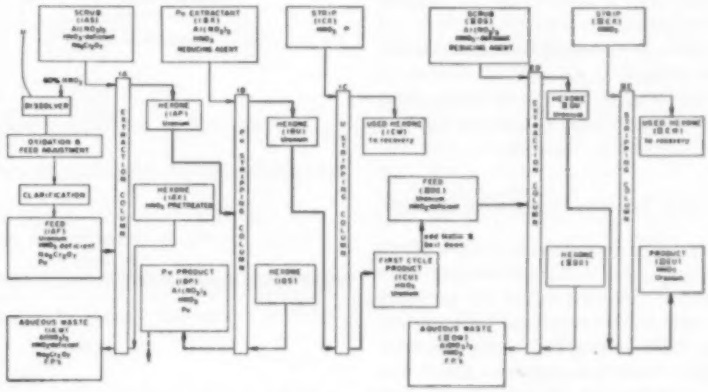


Fig. 1. Schematic flowsheet for first redox cycle and second uranium cycle.

A CHELATION PROCESS FOR SEPARATION OF URANIUM, PLUTONIUM, AND FISSION PRODUCTS

It is possible to separate plutonium, uranium, and fission products by a chelation process that uses thenoyl trifluoroacetone (TTA). In this process plutonium in the tetravalent state is first extracted away from uranium and all fission products except zirconium with a TTA solution in benzene (Figure 5). Traces of fission products are scrubbed from the plutonium-zirconium-bearing solvent with nitric acid. The plutonium is then selectively stripped from the solvent with dilute nitric acid containing a reducing agent, which reduces the plutonium to the insoluble trivalent state. After the zirconium has been removed by a nitric acid-oxalic acid solution scrub, the solvent is ready for reuse.

The uranium, which is contained in the aqueous raffinate from the plutonium extraction cycle, can be extracted with a TTA solution in hexone. The solvent containing the decontaminated uranium is stripped with nitric acid. Part of the decontaminated uranyl nitrate solution is returned to the uranium extraction contactor and used to scrub residual fission products from the uranium-bearing solvent.

The comparative advantages of this process are that only one cycle each is required for plutonium and uranium decontamination, and that the radioactive waste streams contain only dilute nitric acid and oxalic acid, which simplifies the waste disposal problem. The process has the marked disadvantage, however, that the rate of chelation is slow.

25 PROCESS, HEXONE SOLVENT

The separation and decontamination of enriched uranium from fuel elements such as those used in the materials testing reactor, the swimming pool reactor, or the aquarium reactor can be accomplished by solvent extraction with hexone from nitric acid solutions. The process is similar to the Redox process except that the separation and decontamination of plutonium are not required

since only small quantities of plutonium are produced in enriched uranium fuels. The plutonium in the feed stream to the 25 process follows the fission products into the aqueous waste from the first- and second-cycle extraction columns. Aluminum present as a uranium diluent and cladding material in the fuel element serves as the salting agent in the solvent extraction process.

The process developed for recovery of uranium from nitric acid solution containing aluminum consists in the following steps: dissolution of uranium or uranium-aluminum alloy in nitric acid with mercuric nitrate for aluminum dissolution; feed clarification by filtration without filter aid through a sintered stainless steel filter; feed adjustment to acid deficiency; and separation of the uranium from fission products and plutonium in three cycles of solvent extraction with the use of methylisobutyl ketone as the solvent. Plutonium is separated from the uranium in the second cycle after being reduced to the trivalent inextractable state with a reducing agent added with the scrub stream. Small quantities of plutonium are discarded with the fission products if the fuel is highly enriched. If partially enriched fuels are used, a modification of the Redox process can be used to recover plutonium.

An over-all chemical flowsheet showing two cycles of solvent extraction is given in Figure 6. Decontamination factors for two cycles of hexone extraction are shown in Table 6.

25 PROCESS, TRIBUTYL PHOSPHATE SOLVENT

Tributyl phosphate in hydrocarbon diluent may offer some advantages over hexone for the extraction of uranium from solutions containing aluminum. For the TBP-25 process the fuel dissolution and feed preparation steps are similar to those described for the hexone process except that acid rather than acid-deficient conditions are used. The TBP process for uranium-aluminum alloy processing is a modification of the TBP extraction process for plutonium and uranium (Purex process). Laboratory test results with high levels of activity for a TBP uranium-aluminum alloy process have been established. A schematic flowsheet is shown in Figure 7.

The feed solution, containing aluminum nitrate and uranium, is solvent-extracted with TBP in hydrocarbon diluent under acid, rather than acid-deficient conditions. The organic stream in the compound extraction-scrub column is scrubbed with a solution of aluminum nitrate and nitric acid. Uranium is stripped from the organic phase in a second column with dilute nitric

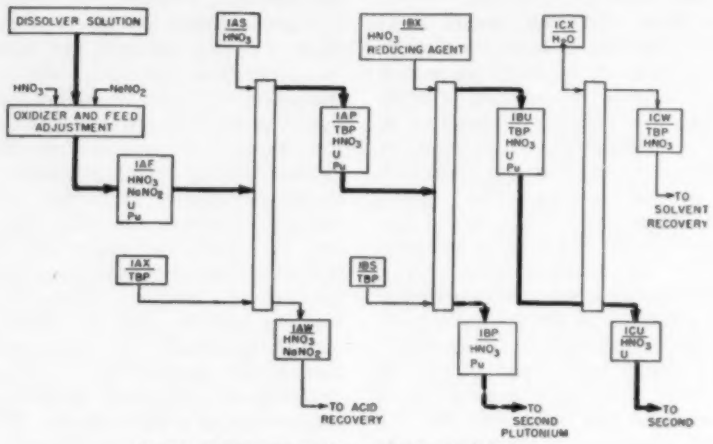


Fig. 2. Purex process first cycle chemical flowsheet.

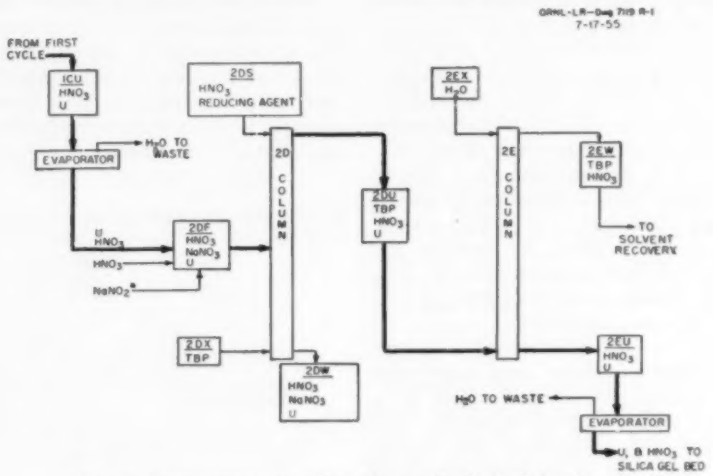


Fig. 3. Purex process second uranium cycle chemical flowsheet.

Table 5.—Purex Decontamination Factors

	log D.F. After 2 Cycles of Solvent Extraction		After Absorption	
Product	β	γ	β	γ
U	6.82	6.43	6.99	6.81[a]
Pu	6.89	6.30	7.51	7.20

[a] Residual fission product β and γ activities in the uranium product were 3 and 100% respectively of those of natural uranium in secular equilibrium with its decay products for fuel that had decayed about 100 days.

Table 6.—Hexone-25 Decontamination Factors

	log D.F.		
Constituent	1st Cycle	2nd Cycle	Over-all
Gross β	4.04	2.41	6.45
Gross γ	3.84	2.36	6.20
Pu α	1.30	1.95	3.25

Table 7.—TBP-25 Process Decontamination Factors

	log D.F.	
Constituent	1st Cycle	2nd Cycle
Gross β	5.48	>2.48
Gross γ	3.17	3.40
Pu	>4.00	>2.00

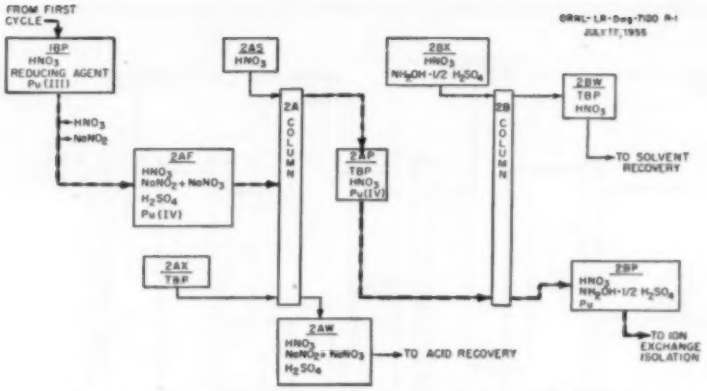


Fig. 4. Purex process second plutonium cycle chemical flowsheet.

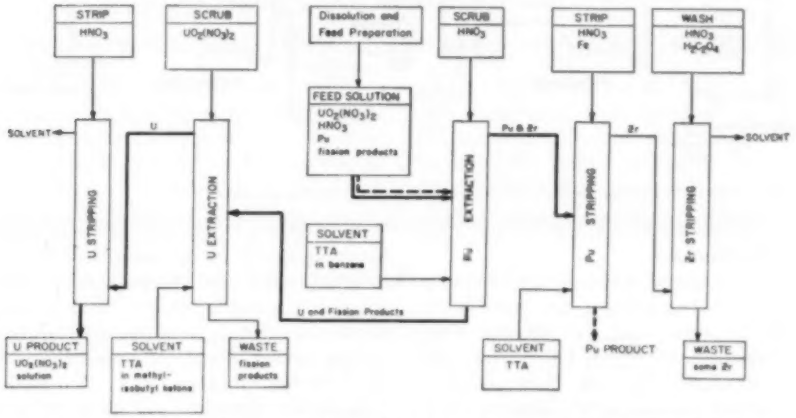


Fig. 5. Schematic flowsheet for U, Pu, and fission product separation by TTA chelation.

Table 8.—β, γ Decontamination, Th-U Separation in Thorex Process

Factor	Over-all	log of factor Through A-Column	Through B-Column	Through C-Column	Through Isolation[a]
Pa^{233} γ decontamination	4.30	4.23	4.30	....	....
TRE β decontamination[b]	5.30	5.28	5.30	....	....
Th-U^{233} decontamination	3.00	....	3.00	....	....
Pa^{233} γ decontamination	6.84	4.23	4.30	4.61	6.84
TRE β decontamination[b]	8.30	5.28	6.30	7.30	8.30
U^{233}-Th separation	7.30	....	4.30	5.00	7.30

[a] Includes silica-gel column plus cation absorption and acetate elution. Further decontamination from radioactive and ionic constituents is obtained in the subsequent peroxide precipitation step.

Editor's Note:[b] 1st TRE (Total Rare Earths) β D.F. (5.3) refers to decontamination through B-column.[b] 2d TRE β D.F. (8.3) refers to decontamination through Isolation system which is an addition to Th-U separation and includes above D.F.

acid. This aqueous product is evaporated and used as feed to a second extraction cycle where TBP in hydrocarbon diluent is used as the extractant. A reducing agent is added to the nitric acid scrub to reduce any plutonium to the nonextractable Pu(III) state. Product from the second-cycle stripping operation is passed through a silica-gel bed to ensure removal of the last traces of fission products. After the silica-bed adsorption, uranium may be concentrated by evaporation or by absorption and elution from an ion-exchange resin.

Decontamination factors and losses are given in Table 7.

HEXONE-23 AND INTERIM-23 PROCESSES

These processes are designed for the specific recovery of U^{233} from irradiated thorium metal. The former may be utilized only on long-decayed material (material that has decayed until U^{233} losses as protactinium (Pa) are very low) since it does not provide effective separation from the highly radioactive Pa^{233}, whereas the latter can be used after very short decay periods. The aqueous wastes from these processes contain the thorium, fission products, and/or Pa^{233} and must be permanently stored in stainless steel tanks. Neither process is designed to recover and decontaminate thorium.

The Hexone process (Figure 8), similar in many respects to the 25 process, utilizes acid-deficient aluminum nitrate as the aqueous salting agent to permit U^{233} extraction and decontamination. Thorium is sufficiently inextractable in the hexone to permit separation factors of greater than 10^4. Decontamination factors for most fission products are greater than 10^5. The decontaminated product is stripped from the hexone into nitric acid, subsequently evaporated and given a final clean-up in laboratory equipment.

The Interim-23 process (Figure 9) utilizes TBP in an aromatic-free paraffinic diluent as the preferential U^{233} extractant. Such a system offers excellent separation of the product from highly radioactive materials, as well as from the thorium. The product is stripped into dilute nitric acid; passed through a silica-gel column for adsorption of traces of fission products; through a small resin column for removal of ionic impurities, such as corrosion products and thorium; and finally through a larger resin column for absorption of the U^{233}. This series of continuously operated steps is effective for the final concentration and decontamination of the product from both radioactive and ionic impurities. After its subsequent elution from the column as uranyl acetate, the product can be precipitated as the peroxide, and finally redissolved in nitric acid. Total fission product activity in the final uranyl nitrate can be as low as 50 counts/(min.)/(mg. U^{233}).

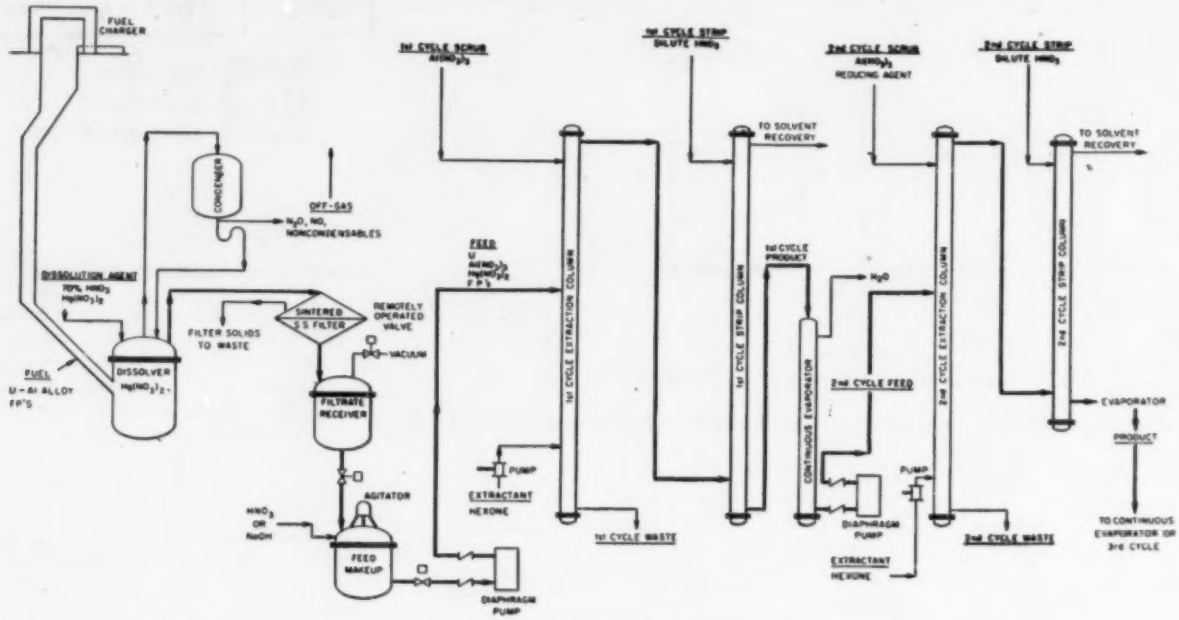


Fig. 6. Schematic flowsheet: two cycles of hexone solvent extraction for uranium-aluminum alloy.

fission-product separation

THOREX PROCESS

The Thorex process has been developed for separating and decontaminating thorium, U^{233}, and Pa^{233} from neutron-irradiated thorium. It is a solvent-extraction process which employs tri-*n*-butyl phosphate as the extractant, nitric acid catalyzed with fluoride ion as the thorium-dissolution agent, and either aluminum nitrate or nitric acid as the salting agent. The U^{233} product is isolated by ion exchange.

A fertile element such as irradiated

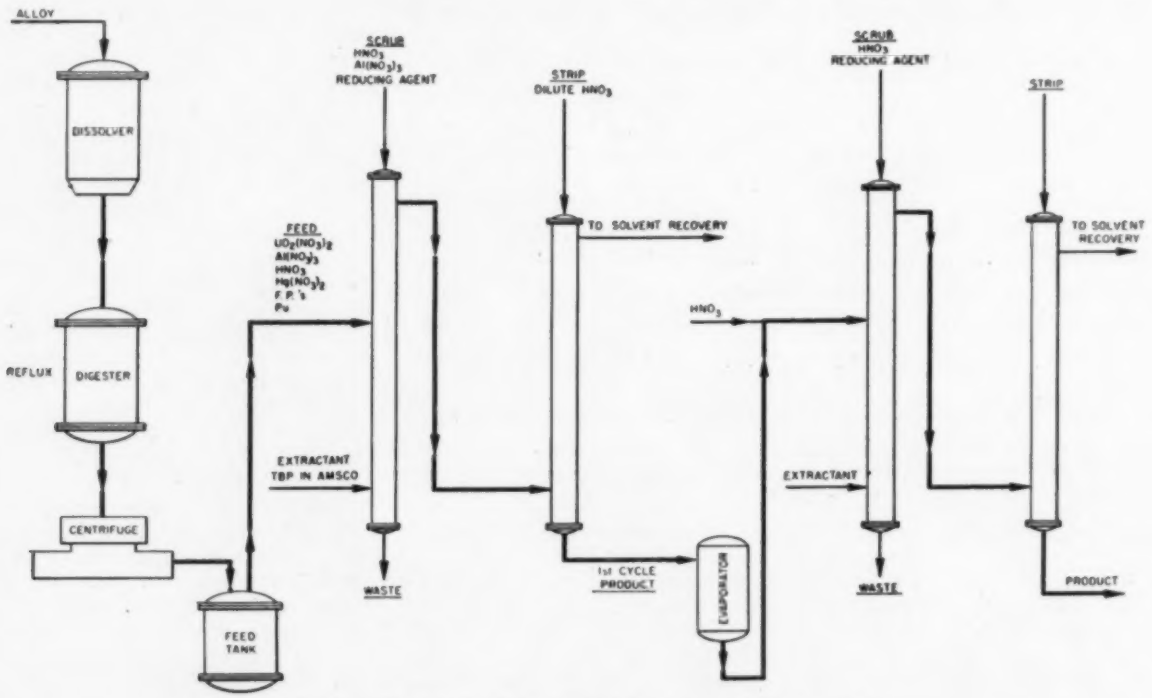


Fig. 7. Schematic flowsheet, TBP-Amsco extraction of uranium-aluminum alloy.

fission-product separation

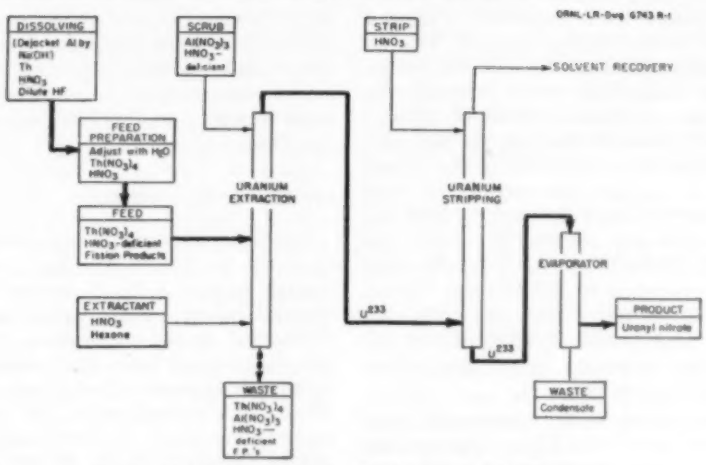


Fig. 8. Chemical flowsheet for the hexone interim-23 process.

thorium metal jacketed with aluminum is dissolved in concentrated nitric acid. The catalysts fluoride ion and mercuric ion are used to catalyze the reaction of thorium and aluminum respectively. Excess nitric acid is required to dissolve refractory thorium oxide, which may be present in thorium metal. Feed dissolution is followed by a digestion step for the removal of excess nitric acid.

The aqueous feed is introduced near the middle of the compound extraction-scrub column. An aqueous scrub solution of acid-deficient aluminum nitrate,

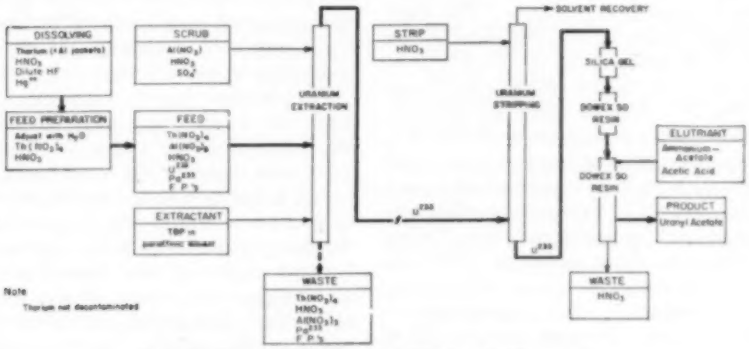


Fig. 9. Chemical flowsheet for TBP interim-23 process.

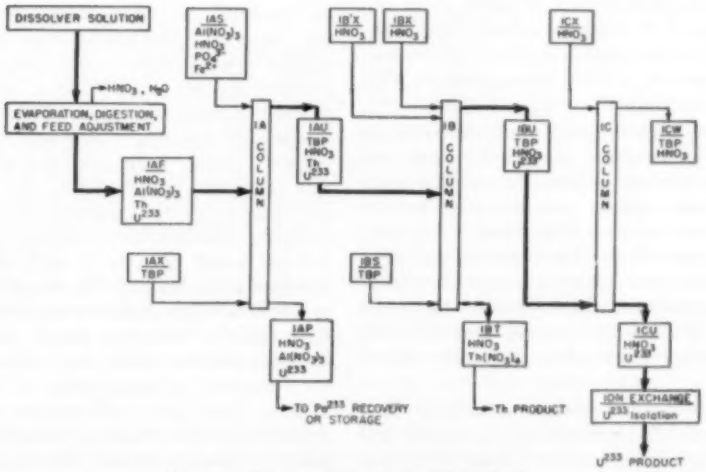


Fig. 10. Thorex process chemical flowsheet.

ferrous sulfate, and dilute phosphoric acid enters at the top of the column. Tributyl phosphate diluted with Amsco 125-82 (an inert paraffinic diluent) extracts the thorium and U^{233}. The primary TBP-nitrate complexes of these elements are $Th(NO_3)_4 \cdot 4TBP$ and $UO_2(NO_3)_2 \cdot 2TBP$. The corresponding complex of nitric acid is $HNO_3 \cdot TBP$.

In TBP extraction of thorium it is essential that the diluent be free of aromatic organic compounds to prevent the formation of two phases in the organic streams. A second organic phase results from the extraction of a polymerized TBP complex of thorium (corresponding to the complex ratio equivalent of $Th(NO_3)_4 \cdot 2.5TBP$) by small traces of aromatics in the paraffinic diluent.

Decontamination from rare-earth fission products and from protactinium is sensitive to the degree of saturation of the organic solvent. The organic effluent is not fully saturated with thorium; however, near the feed plate saturation is almost attained, owing to reflux in the scrubbing section. This saturation with thorium suppresses the extraction of the rare-earth fission products, which would be extracted in the presence of a large excess of TBP and which normally undergo extensive reflux in the lower section of the extraction column. Owing to the nitric acid-deficient conditions of the aqueous phase, the Pa^{233} and most of the troublesome fission products are not extractable; however, the aqueous scrub solution provides for additional removal of these from the product extract. Phosphate ion is included in the scrub solution to assist in decontamination from protactinium, and ferrous ion is included to prevent extraction of an oxidized chromium compound that is produced during the head-end treatment of the feed.

The aqueous phase from the extraction column contains aluminum nitrate, is acid deficient, and contains any Pa^{233} that has not decayed to U^{233}, fission products and other impurities. It is reduced in volume by evaporation to permit minimum storage volumes.

The organic extract from the extraction column, containing Th^{232}, Th^{234}, U^{238}, and tarces of fission products, and any Pa that may be present is introduced into the middle of the partitioning column. The thorium is stripped

into an aqueous phase of nitric acid, which flows down the column; this aqueous solution is scrubbed by the organic stream of TBP introduced in the bottom of the column. The aqueous strip stream represents the combined flow of a nitric acid solution introduced some distance below the top of the column and a water stream introduced at the top of the column. Aqueous conditions are thus maintained slightly acidic, which will permit thorium stripping into the aqueous stream and retention of the U^{233} in the organic stream. The water stream entering the top of the column permits some U^{233} reflux, but it is necessary to remove nitric acid from the organic phase so that the subsequent uranium stripping cycle will operate at maximum efficiency.

The organic effluent from the partitioning column containing all the U^{233} and traces of nitric acid, is passed to the bottom of the uranium stripping column. An aqueous phase of dilute nitric acid is introduced at the top of the column and serves to strip the U^{233} from the rising organic stream. The aqueous effluent then is passed through a silica-gel column for removal of trace quantities of fission products; a small column

fission-product separation

containing cation exchange resin for the retention of traces of thorium and corrosion products; and a larger cation exchange column for concentrating and further decontaminating the U^{233} product. The effluent from this column is discarded to chemical waste. Product is eluted by a solution of ammonium acetate and acetic acid.

A schematic flowsheet for a one-cycle Thorex process is given in Figure 10.

For decontamination factors for one cycle of extraction see Table 8. One cycle of extraction may not provide adequate decontamination of ruthenium in the thorium stream for highly irradiated feeds.

Auxiliary Processes

SOLVENT CHEMISTRY AND RECOVERY

Hexone used in the extraction of uranium and plutonium from fission products can be treated and recycled for reuse with low over-all solvent loss. Hexone as purchased from the vendor may contain such impurities as mesityl oxide, methylisobutyl carbinol, and an aromatic substance, possibly mesitylene. These impurities, which decrease the uranium and fission-product separation, are all oxidizable and may be destroyed and removed by agitation of the solvent with a sodium dichromate-nitric acid solution, followed by washing with sodium hydroxide solution and stream distillation from a sodium hydroxide heel. This procedure is also adequate for removing fission-product contamination from used solvent. Investigation of the stability of hexone to radiation is reported in another paper.

Experience with commercial-grade tributyl phosphate (TBP) indicated that certain impurities [traces of butanol and of mono- and dibutyl acid phosphate (MBP and DBP)] present were harmful in radiochemical separation processes. Separation of uranium and plutonium from fission products was not so effective with commercial TBP as with butanol-free TBP, the difference being due to an increased (fivefold) β-activity distribution coefficient in the scrub section.

Although TBP is satisfactory initially, continued use of the solvent results in gradual degradation. The alkyl acid phosphates have a marked effect on plutonium behavior in the Purex process, the DBP by its strong complexing of Pu(IV) and the MBP by its tendency to form a precipitate with Pu(IV). These contaminants are known to react similarly with U(VI) and would pose a problem in TBP systems demanding extremely high uranium recovery. Owing to the complexing action of DBP, Pu (IV) loss during stripping becomes excessive unless the DBP concentration is kept very low. However, complexing of Pu(III) by the organic-soluble DBP is relatively weak. At DBP concentrations up to 0.01%, plutonium may be readily reduced and stripped. The behavior of the aqueous-soluble MBP has not been thoroughly studied, but no major process difficulties associated with this contaminant have been encountered.

Owing to the acidic natures of MBP and DBP, they are readily removed from the used solvent by washing with a dilute sodium carbonate or caustic solution and then with dilute nitric acid. This procedure also removes traces of uranium and residual fission products. The solvent is reconditioned after each pass through the process, and all fresh solvent is treated the same way before use.

Laboratory studies indicated that Amsco 123-15 naphtha is generally acceptable for use as the solvent diluent in the Purex process. Although tests indicated that this material is not appreciably affected by the chemical environment and radiation exposure, the cumulative effects of such exposures in extended reuse could not be predicted. Another diluent, Amsco 125-82, is used for the Thorex process.

OFF-GAS IODINE REMOVAL

Irradiated fuels after decay periods of as much as 100 to 130 days contain enough residual I-131 to require iodine removal before dissolver gases can be discharged to the atmosphere. Iodine can be removed from gas streams by reaction with heated silver or with silver nitrate in a packed tower. A column, packed with silver nitrated-coated Berl saddles, removes 99.9% of the iodine from a dissolver off-gas. Most of the iodine is removed in the first few inches of packing.

Equipment and Engineering Concepts

CONTACTORS USED FOR SOLVENT EXTRACTION

The principal types of continuous contactors used in the liquid-liquid extraction of fissionable and fertile material are gravity columns, including packed and perforated-plate columns, and powered contactors, including pulsed columns and mixer-settlers.

The packed tower contains some form of a packing, such as stainless steel Raschig rings, to provide a tortuous route for the droplets of dispersed phase to follow through the continuous phase, enhancing the contact of the two phases. For a given application the type of packing used depends largely on the chemical nature of the system and the processing requirements, whereas the packing depth (packed height) depends on the degree of separation required.

Mixer-settler equipment, which can be operated at high-stage efficiency can be used. Horizontal-type mixer-settlers usually require less height but greater canyon length than vertical solvent extraction columns of the same processing capacity. Pump-type mixer-settlers have been developed. In this compact mixer-settler, the mixing chambers are separated from the pumping chambers by partitions. A centrifugal pump agitator in each mixing chamber picks up both incoming phases in a hollow vertical shaft and discharges them radially, intimately mixed, into the adjacent settling zone, thus producing the necessary hydraulic head for stage-to-stage flow and maintenance of the liquid-liquid interface in the desired position in each stage. The two-phase flow in each settling zone is cocurrent

fission-product separation

while flow between stages is countercurrent. There are no submerged seals or bearings; the motor-impeller assembly may be removed or replaced by remote control.

The pulsed perforated-plate column provides a significant, often more than twofold, reduction in column height from the heights needed with a conventional packed column. In the pulsed column an up-and-down pulsing motion is superimposed on the net countercurrent flow of the liquid phases through a series of stationary, spaced, horizontal perforated plates. As an alternative to the perforated plates, a pulsed column may employ Raschig rings or other packing.

In the case of perforated-plate columns the pulsing also performs another important function in that it provides the means of countercurrent flow of the aqueous and organic phases. The specific gravity difference between the two phases is usually not sufficient to cause a significant countercurrent flow through the small holes in the perforated plates. Consequently, the net flow of the light phase up and the heavy phase down the column is caused almost entirely by the actions of the pulse generator and the stream pumps.

The most important advantage of pulsed columns over packed columns is the fact that, for the same extraction duty, they can be made much shorter. Additional advantages are a less pronounced dependence of extraction effectiveness (H.T.U. values) on the throughput rate and, in the case of sieve-plate columns, the greater ease of a temporary shutdown and start-up with the characteristic of very little flow through the plates in the absence of pulsing. The need of a pulse generator, with its initial cost and maintenance requirements, is a disadvantage.

DESIGN CONCEPTS

Any detailed discussion of the engineering and equipment design which must be done for a radiochemical plant cannot be summarized in a paper such as this. However, a survey of solvent extraction technology would be incomplete without some general discussion of possible approaches for equipment and plant design.

A typical radiochemical processing plant has certain basic functional components. These components, which may be considered as unit processes, can be grouped as follows:

1. Storage of irradiated reactor fuel or fertile reactor elements to permit decay of short-lived fission products
2. Dissolution of fuel elements in the appropriate chemical reagent and subsequent clarification and chemical adjustment to provide feed for the separation process
3. Storage of feed solutions until introduced into the separation process
4. Separation of fissionable or fertile materials from fission products and transuranic elements
5. Collection and analysis of fission-product-bearing waste streams
6. Collection of product, analysis, and preparation for shipment
7. Preparation, distribution, and recycling of chemical process reagents

To support these main line chemical processes and to handle highly radioactive wastes, the following supporting facilities are required:

1. Analytical laboratory
2. Waste processing, storage, and disposal of both liquid and gaseous wastes
3. Maintenance shops and personnel
4. Service facility for production and distribution of all common process services
5. Mechanical handling equipment for manipulating shielded fuel carriers
6. Health physics facility and personnel for biological protection of operating personnel
7. Security and protection facilities and personnel
8. Site development such as roads, main power distribution, primary water supply, sewage disposal
9. Facilities for all standard administrative functions

The design and conception of a radiochemical plant involves consideration of many factors that are foreign to standard chemical plant design. A limited number of these have been selected for discussion.

A choice between batch and continuous processing must be made. Batch processing is advantageous for good fissionable material accountability since the location of all fuel material in the processing plant can be determined by following discrete batches through a processing plant with remote instrumentation and analytical control. Advantages of continuous processing are reduction of the number of process pieces, and hence the cost, and the greater compatibility of continuous techniques with criticality control of solutions containing U^{235} or Pu^{239}.

Criticality of solutions in the chemical plant must be considered. Critical conditions of systems containing fissionable material result from the accumulation of a sufficient mass of fissionable material in a geometric configuration which minimizes loss of neutrons produced by the fission of the fissile element adequately to allow a chain reaction to progress. Solutions containing U^{235} or Pu^{239} can be made to go critical, or can do so by accident, during chemical processing. Obviously, the chemical plant designer must provide a system in which it is impossible to produce critical conditions.

A thick radiation shield is required to provide protection for operating and maintenance personnel. All process lines, contaminated air, liquid wastes, and radioactive auxiliary equipment must be shielded. Shields in a radiochemical plant are erected for the biological protection of operating personnel from penetrating γ rays emitted by decaying fission products; the shielding of α particles presents no problem because of the short range of these particles in any material; beta particles are stopped by shields much thinner than those required for the penetrating photons of γ rays.

Radioactive decay cooling can be accomplished in water-filled basins or "canals," which give thermal cooling for fuel elements from reactors as well as providing a γ-ray shield. A water shield for storage and cooling of radioactive materials is reasonably inexpensive. Bulk shielding is usually concrete and ranges in thickness from 1 to 6 ft.

Special shields for plant appurtenances such as samples, pump blisters, carriers, and dissolver chargers usually are made of lead because of its higher density and consequent lower volume requirement. Lead shielding specialties are even more expensive than concrete mass shielding, since normally they are integrated with some mechanical-handling device for radioactive materials.

All process equipment must be operated remotely from outside a processing cell. For each process vessel a liquid-level indicator and a specific-gravity indicator-recorder are required. If temperature is important, a remote-reading temperature recorder is necessary. All valves inside processing cells must be bellows- or motor-operated; they must also be packless and contain no plastic seats or poppets. The measurement of flow of radioactive solutions is greatly complicated because of lack of accessibility for maintenance and possibly low volumetric flow rates.

All equipment used in handling radioactive solutions must be as maintenance-free as possible. Complicated processing equipment with moving parts requiring lubrication cannot be used. Pumps that have packings are not used since all packings require replacement. Extensive and expensive precautions must be taken to assure good workmanship in all equipment; all piping must be absolutely leaktight. Equipment that may require frequent maintenance is removed from processing cells and installed in shielded, accessible compartments. Materials of construction must be resistant to process and decontaminating solutions.

Most decontaminating reagents are liquids and are usually corrosive; mineral acids and combinations of same are used extensively. Process equipment and piping must therefore be resistant to the corrosive attack of decontaminating reagents. To prevent the exterior of process vessels and piping in a process cell from becoming permanently contaminated, the same corrosion resistance must be provided. Therefore, use of stainless steel for all equipment and piping inside processing cells is advisable. Equipment supports are commonly stainless steel or carbon steel coated with corrosion-resistant organic coatings. The concrete surfaces in a processing cell must also be protected. Stainless steel floors are frequently used. Walls are carefully finished to a smooth surface, etched with acid, and coated with protective organic coatings.

In spite of all precautions to prevent equipment or piping failure, it must be recognized that some maintenance will be required. Three basic philosophies for maintenance systems can be used:

1. **Remote maintenance: equipment and piping designed such that it can be removed by remotely operated mechanical devices, discarded, and replaced.**
2. **Direct maintenance: equipment and processing cells designed such that decontamination from fission product activity can be done preceding direct repair.**
3. **Underwater maintenance: equipment installed as for direct maintenance but located such that mechanical operations can be accomplished through a water cover if necessary; process cell built such that equipment can be covered with sufficient water for shielding during maintenance.**

fission-product separation

separation of U^{233} and Th fission products with tributyl phosphate

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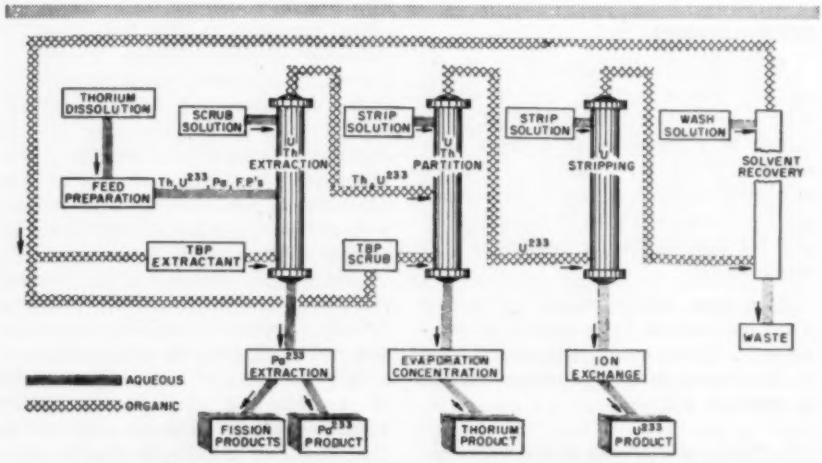
and Others

U.N.–A/Conf. 8/P/540

Process Flowsheet

The general characteristics of the process are given in the accompanying flowsheet. The irradiated thorium metal or oxide is dissolved in a nitric acid solution containing fluoride ion as a catalyst. The thorium nitrate solution is adjusted to feed specifications and is introduced into the first column, where the thorium and U^{233} are extracted by the tri-*n*-butylphosphate (TBP). Pa^{233} and fission products remain in the aqueous phase. An aqueous scrub solution of acid-decient * aluminum nitrate containing phosphate ion is introduced at the top of this column to remove small amounts of Pa^{233} and fission products from the organic product stream. The aqueous stream leaving the bottom of the column is concentrated by evaporation and is then introduced into a smaller recovery system where the Pa^{233} is removed on a carrier; fission products remain in solution and are routed to radioactive-waste storage. The organic stream containing the decontaminated thorium and U^{233}, flows continuously to the middle of a second column, where the thorium is preferentially stripped into dilute nitric acid solution introduced at the top of the column. An organic scrub stream is introduced into the bottom of this column to reextract small amounts of U^{233} from the aqueous stream, and the latter proceeds to an evaporator for concentration of the thorium product. The organic stream containing the U^{233}, flows continuously to the bottom of a third column, where the uranium product is stripped into a slightly acidic water solution and then is passed through an ion-exchange resin column for concentration and final purification. The organic stream finally flows continuously to a solvent-recovery column where acidic decomposition products of TBP are removed by washing with dilute sodium carbonate solution. The recovered solvent is centrifufed, and recycled in the process.

* **Deficiency of free nitric acid in solutions of hydrolyzed nitrate salts, e.g., of aluminum or thorium. Such solutions may be considered to contain quantities of basic salts such as $Al(OH)(NO_3)_2$ or $Th_2(OH)(NO_3)_7$; however, they have acidic reactions, i.e., from pH 2.0 to pH 4.0.**



Process flow diagram for separation of uranium from irradiated thorium.

SURVEY OF SEPARATIONS PROCESSES —OTHER THAN SOLVENT RECOVERY

SPECIAL NUCLEAR ISSUE

fission-product separation

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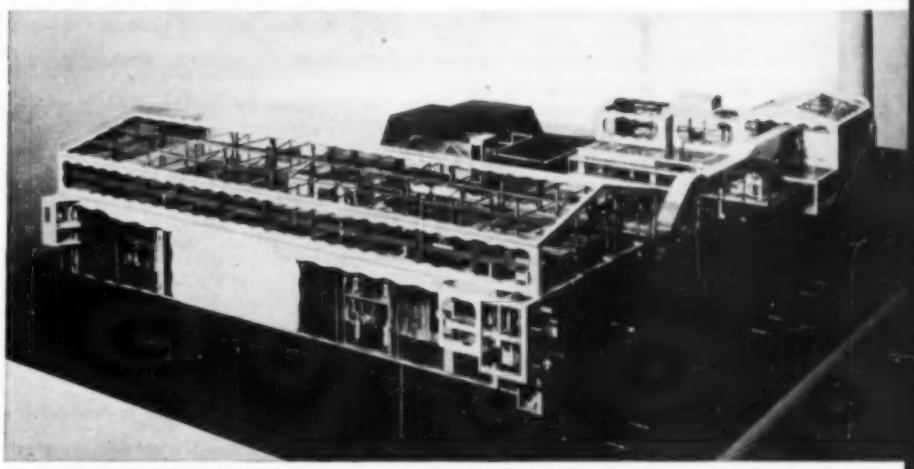
U.N.-A/Conf. 8/P/823



A general view from the southwest of a simplified model of the Idaho Chemical processing plant. The large building in the foreground is the main process building, showing (lower left center) the equipment employed in reducing aluminum-uranium fuel elements to the chemical solution used in the uranium-recovery operation. On the upper level are the supply reservoirs for process chemicals. The waste-handling area is in the background. This plant, located at the National Reactor Testing Station, is operated by Phillips Petroleum Company under contract to the A.E.C.

When fossil fuels are burned to produce heat, essentially complete consumption of fuel is obtained at once. Therefore, there is no fuel recovery problem. Nuclear reactors do not give this completeness of fuel burn-up because of premature adverse reactivity change or physical damage of fuel. Consequently, several cycles of burn-up and intervening recovery operations are necessary to get the equivalent of a complete utilization of fuel. A separations process for the fuel recovery must, therefore, be capable of high yields and low cost per cycle. Moreover, ideally the process should accomplish this with a minimum of holdup time to avoid a large inventory of fissionable material.

The degree of decontamination (removal of an undesirable constituent) required of reprocessing steps may vary widely. For example, with homogeneous reactors it is generally conceded that partial decontamination will suffice. This is expected to be done continuously on at least a portion of the fuel circulated through the reactor. Although only partial decontamination is needed, it must be derived without deleterious effects on reactor operation. This means that the purification process must be reliably continuous and must not introduce into the fuel substances which are harmful to reactor operation.

In the cases of heterogeneous reactors, substantially complete decontamination has been demanded as of the present. This permits direct-contact fabrication of fuel assemblies from the recovered fuel. Such a restriction limits the selection of separations processes to those capable of thorough decontamination. The problem is further complicated in many instances by the use of fuels, fuel claddings, and bonding materials which are extremely difficult to dissolve and to handle conveniently during reprocessing. The successful development of methods for remotely fabricating fuel elements for heterogeneous reactors would alleviate the demands on separations process decontamination for such reactors. The result would be a wider choice of processing schemes. It is believed that some of these have good prospects of minimizing the total costs in a reactor complex to produce power.

Many different separations methods are being investigated for reactor fuel recovery and purification. They are listed in Table 1. These are in various stages of study or development in order to permit the optimum selection of reprocessing methods for various reactors. A review of solvent-extraction processes which use organic solvents with aqueous process solutions is presented in another paper. Therefore, the review here will be concerned with the first four methods shown in Table 1.

Precipitation Processes

Precipitation methods have played a major role in laboratory investigations of the fission process; numerous examples have been described. Therefore, this discussion will be confined to large-scale applications of this type of separations method.

The most important example is the Bismuth Phosphate Process (BPP), which uses $BiPO_4$ and LaF_3 as carrier precipitation agents. It has been the most thoroughly investigated and developed of all the precipitation methods and has culminated in a successful production-scale use of the process to recover and decontaminate plutonium from irradiated natural uranium.

The Bismuth Phosphate Process recovers plutonium but not uranium. The uranium is, however, recoverable from the process wastes by other methods. The bismuth process accomplishes the quantitative separation of plutonium from uranium and fission products according to the schematic flowsheet given in Figure 1.

Separation of plutonium from uranium and from some of the fission products is obtained in an extraction step. In this stage uranyl nitrate feed solution is treated with $NaNO_2$ to adjust the valence of plutonium to +4. A complexing agent to prevent precipitation of uranium, $SO_4^=$, is added. Coprecipitation of $BiPO_4$ and $PuPO_4$ is arranged.

Following the extraction step the precipitate is dissolved in nitric acid and two cycles of decontamination of the plutonium are performed by $BiPO_4$ precipitations. Each cycle has a by-product precipitation

(in which the plutonium remains in solution) followed by a product precipitation (in which plutonium has been brought down with the precipitate). Precipitations are effected with +4 and +6 states of plutonium in the product and by-product precipitations, respectively.

Following the two decontamination cycles there is a series of operations termed collectively as concentration step. This comprises a $BiPO_4$ by-product precipitation, a LaF_3 cycle of by-product and product precipitations and, finally a metathesis of the LaF_3 product precipitate with KOH to give a mixture soluble in nitric acid for ultimate plutonium isolation. The final isolation of plutonium is performed by a peroxide precipitation with H_2O_2.

Decontamination of the uranium is accomplished by repeated crystallizations of uranyl ammonium phosphate. The continuous and adequate purification of fuel solutions from certain of the aqueous homogeneous reactors appears promising with a precipitation-type method according to currently available results. The method is believed to be simpler and more economical than other types thus far studied.

Experience has shown precipitation processes to be flexible and comparatively easy to scale-up from laboratory

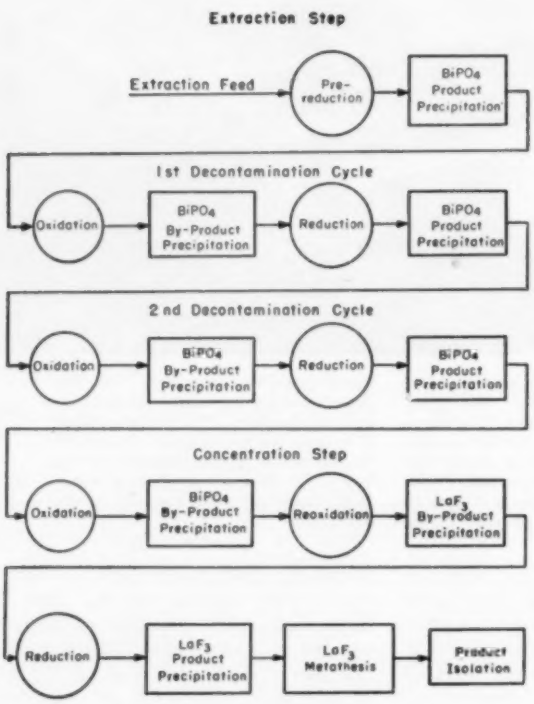


Fig. 1. Schematic flowsheet for bismuth phosphate process (extraction step).

The over-all recovery of plutonium has been above 95% for the Bismuth Phosphate process. The loss of 5% or less is rather evenly distributed to the various waste streams. Typical decontamination factors obtained in the course of the different process steps are given in Table 2. They give evidence that thorough decontamination of plutonium from fission products is achieved. The separation of uranium from plutonium in the extraction step is also excellent as indicated by low-uranium content in the plutonium product from the process.

Another precipitation method intended for large-scale purposes is one that has been developed for recovery of uranium from the B.P.P. The method has been successfully tested on a pilot-plant scale. results. This is because the large-scale equipment is generally simple in design. Probably the most complicated piece of equipment is that required for the solid-liquid separations. Centrifugation has been the preferred method for this operation, at least in the case of the B.P.P. Remote operation and maintenance have proved feasible for large-scale installations.

Two significant disadvantages should be mentioned relative to precipitation-type separations processes. The precipitation methods are (1) not as adaptable to continuous operation as, for example, solvent extraction or fractional distillation methods, and (2) not so capable of achieving high yields of recovery as some of the other methods.

Table 1.—Separations Methods for Fuel Recovery and Purification

precipitation
ion exchange
fractional distillation
pyrometallurgy (high temperature)
solvent extraction

Table 2.—Typical Decontamination Factors Obtained with Bismuth Phosphate Process

	Decontamination Factor	
Operations Step	Individual	Overall
Extraction	7.5	7.5
First decontamination cycle	150	1.1×10^3
Second decontamination cycle	90	1×10^5
Concentration	100	1×10^7

Ion-Exchange Processes

In the atomic energy program, ion-exchange methods have been extensively used in the laboratory to make very difficult separations but have not been taken beyond small-scale pilot plant installations.

One of the most important larger scale applications has been in auxiliary steps with other basic types of separations processes. Ion exchange has proved to be a very effective method for concentrating solutions of plutonium, enriched U^{235} or U^{238}. Comparative studies which have been conducted on various ways to concentrate intermediate or final product streams (such as from solvent extraction separations processes) have resulted in the conclusion that ion exchange is superior to evaporation or precipitation chemes. First, it is a more convenient method than evaporation for accomplishing large-volume reduction factors (in excess of 100-fold on plutonium and other heavy element-containing solutions; at the same time, 2 to 10-fold or more decontamination from zirconium and niobium is often obtained, with some ruthenium removal also effected). Second, it is less likely to introduce impurities, such as corrosion products in the case of evaporation methods, and added chemical reagents in the case of precipitation methods. Third, it frequently achieves significant additional purification in the course of concentrating a particular product stream from main-line separations processes. In some instances the amount of purification is enough to enable elimination of a complete cycle of solvent extraction.

Organic exchangers have been most often used for this purpose. Silica gel,

however, has been successfully used to clean up concentrated uranium solutions from solvent extraction processes. The losses of valuable material have been negligible in applying ion exchange to concentration or added purification steps.

Other significant large-scale utilizations of ion exchange have been in conjunction with the preparation of pure process waters and with the decontamination of large volumes of low-level radioactive wastes from reprocessing or major laboratory installations.

Resins available in early work on ion exchange were quite sensitive to chemical and radiation effects. Recently available resins appear to be considerably more stable; therefore, it is reasonable to expect that there will be a renewed interest in ion-exchange methods for reprocessing operations.

Some of this interest is already evident in connection with continuous processing of solutions from aqueous homogeneous reactors. Work with both inorganic and organic forms of ion exchangers is in progress for this reprocessing problem.

Fractional-Distillation Processes

The potentiality of fractional distillation for fuel recovery has always made an appeal, because the basic principles and technology of fractional distillation have been so well developed. Another significant influence has been the economically attractive possibility of recovering uranium directly as UF_6 by this separative method. This form of uranium product from a process would be advantageous when the recovered uranium is to be sent to a diffusion plant for enrichment. If the recovered uranium is to be converted to metal, it is significant that UF_6 can be readily reduced to UF_4 which, in turn, is readily convertible to metal. One other important factor in favor of a fluoride system is the background of experience in the diffusion plants with this system.

Further advantages of a fluoride system are as follows: The volatility of UF_6 is substantial at reasonable temperatures, not the case with other known stable compounds of uranium. It is encouraging to find that the volatilities of the fission-product fluorides are appreciably different from those of UF_6. This is illustrated in Tables 3 and 4, which summarize the boiling points for a number of fission-product fluorides and of UF_6. Practicable separation of UF_6 from the fission-product fluorides should be achievable by efficient fractional distillation. For this reason, substantial decontamination is likely even with a crude distillation. Complete decontamination requires more efficient distillation. These predictions have been verified with distillations of feed solutions prepared by various techniques of fluorination.

Much of the effort on the research and development of fractional distillation processes has been concerned with the preparation of fluoride-feed solutions from irradiated uranium fuel. Various approaches have been necessary because the starting fuel may be pure uranium metal, mixtures of uranium and diluent metals, or various uranium compounds such as oxides and salts.

In the fluorination of uranium metal with elemental fluorine, control of this gas-solid reaction has proved to be difficult and even hazardous, because the effective rate of heat transfer is too slow to dissipate the enormous heats of chemical reaction. It has been found to be practical to use liquid-phase fluorinating agents, such as ClF_3 (chlorine trifluoride), BrF_3 (bromine trifluoride), and BrF_5 (bromine pentafluoride).

These interhalogen compounds, particularly BrF_3, have convenient liquid ranges, as shown in Table 5.

The dissolution and complete fluorination of uranium metal can be satisfactorily effected with BrF_3 or with ClF_3-HF mixtures at temperatures and pressures such that the liquid phase of the fluorinating agent can be maintained. The liquid phase of the fluorinating agent provides adequate heat transfer from metal to solution. The vaporization and condensation of vapors from dissolver solution provides for the necessary removal of the heat of chemical reaction. It is important that metal always be covered with solution; otherwise, the character of reaction may revert to that of a gas-solid reaction and result in the same problems and hazards as obtained with elemental fluorine.

Subsequently, fractional distillation of the resulting dissolver solution can decontaminate the uranium from the fission products. Small-scale demonstration tests have been conducted on fractional distillation of fluoride feeds from ClF_3-HF or BrF_3 dissolutions of irradiated uranium. The effectiveness of decontamination in such tests is indicated by data in Table 6, which are for ClF_3-HF dissolver solutions. Encouraging results on decontamination have been observed also in laboratory fractional distillations of fluoride-feed solutions prepared from BrF_3 dissolutions of irradiated uranium. Reliable figures for UF_6 recovery are not available because the demonstration tests have been conducted on a relatively small scale. Results are, however, encouraging, and no difficulty is expected in regard to recovery of purified UF_6.

Table 3.—Properties of Nonvolatile Fission-Product Fluorides

Compound	Melting Point, ° C.	Boiling Point, ° C.
CsF	684	1251
SrF_2	1300–1400	2460
BaF_2	1280	2260
YF_3	>1000	
LaF_3	>1000	
CeF_3	1324	
PrF_3	1370	
ZrF_4	[a]	
CeF_4	1460	

[a] Sublimes at 500° C.

Table 4.—Volatile Fission-Product Fluorides in Order of Decreasing Volatility

Compound	Melting Point, ° C.	Boiling Point or Sublimation Point, ° C.
AsF_5	—79.8	—53.2
TeF_6	—37.8	—38.3
RuF_6[a]	?	?
IF_7[b]	5–6	4.5
MoF_6[c]	17.5	35.0
UF_6	64.02[d]	56.4
AsF_3	—6.0	58.0
Te_2F_{10}[b,e]	—14.0	60.0
IF_5	8.5	97.0
NbF_5	78.9	233.3
RuF_5	106.0	313.0
TeF_4	129.6	371.3[f]

[a] Recently reported as very volatile and highly reactive. No conclusive evidence of its formation in fluoride process feed.
[b] No evidence of its presence in fluoride process feed.
[c] Mo is a short-lived fission product.
[d] Triple point.
[e] Reported as relatively unstable.
[f] Decomposes at approximately 194° C.

Table 5.—Properties of UF_6, Br_2, F_2, HF, and Some Interhalogen Compounds

	UF_6	F_2	BrF_5	ClF_3	BrF_3	Br_2	HF
Molecular weight	352.07	38.00	136.92	92.46	174.92	159.83	20.01
Boiling point, ° C.	56.4[a]	—187.92	125.75	11.75	42	58.78	19.54
Melting point, ° C.	64[b]	—217.96	8.77	—76.32	—61.3	—7.3	—83.07

[a] Sublimation point.
[b] Triple point.

It should be noted here that plutonium remains in the nonvolatile residue. The reason for this is that, unlike uranium, plutonium is not fluorinated to the volatile form, PuF_6, under the usual dissolution conditions. Recovery of plutonium from the residue can be obtained by aqueous processes such as solvent extraction. The residues are dissolved in dilute $Al(NO_3)_3$ solution for solvent extraction purposes. The fact that plutonium is fluorinated only to the nonvolatile lower fluorides is advantageous for reprocessing irradiated, highly enriched uranium by fractional-distillation methods. In this instance, plutonium recovery is not important and the small amount usually present is desirably directed to the fission-product wastes. On the other hand, the failure of these dissolving methods to yield volatile PuF_6 is a distinct disadvantage for application of this separations method to irradiated natural uranium. In this instance, recovery of plutonium as well as of uranium is desired.

Cost estimates have been made for the recovery of uranium by fractional distillation and for the recovery of plutonium from the residue by solvent extraction. These estimates show only a slight advantage for the combination of these processes as against the use of a solvent extraction process alone for recovery of both products.

There are known methods for the preparation of PuF_6, but they are not convenient for large-scale operations which begin with irradiated uranium metal. Work is in progress with the objective of finding more satisfactory conditions under which both plutonium and uranium may be obtained as volatile hexafluorides. Success in this respect, together with practical methods of handling PuF_6, would make the fractional distillation method a superior separations process for irradiated natural uranium. Until then, its outstanding promise is for the reprocessing of highly enriched uranium where the plutonium problem is absent.

There are other situations where the plutonium problem is also absent and where this method may be used to complete purification of uranium. Some obvious examples are ore concentrates and uranium product streams from intermediate stages of solvent extraction processes.

Enriched fuels are frequently manufactured with major amounts of alloying agents. Some of these alloy mixtures are not amenable to nitric acid dissolution nor even to interhalogen dissolution at convenient temperatures.

Successful dissolutions of such alloys have been accomplished at 500-700° C. with fused salt mixtures through which hydrogen fluoride is first dispersed, followed by either F_2 or BrF_5. As much of the fluorination and dissolution as possible are effected with hydrogen fluoride, which is relatively inexpensive. The resulting UF_4 is fluorinated completely to UF_6 by F_2, or preferably by BrF_5, which can be more easily recycled than F_2. Other refractory reactor fuels, such as oxides and salts of uranium, may be similarly dissolved and completely fluorinated.

The dissolver solutions so prepared are stripped of UF_6 content with considerable decontamination of UF_6 obtained at the same time. Overhead vapors are then fractionally distilled to complete the purification of UF_6. The fission products are principally in the fused salt mixture, which may be a better storage medium than aqueous solutions for long-term storage of these by-products.

The potency of the aforementioned dissolution procedure poses problems of containment, especially at the F_2 or BrF_5 addition step. Nickel and Monel are only moderately satisfactory materials of construction. However, both materials have been found satisfactory for laboratory and pilot plant work on BrF_3, BrF_5, and ClF_3-HF metal dissolutions at moderate temperatures and subsequent fractional distillations.

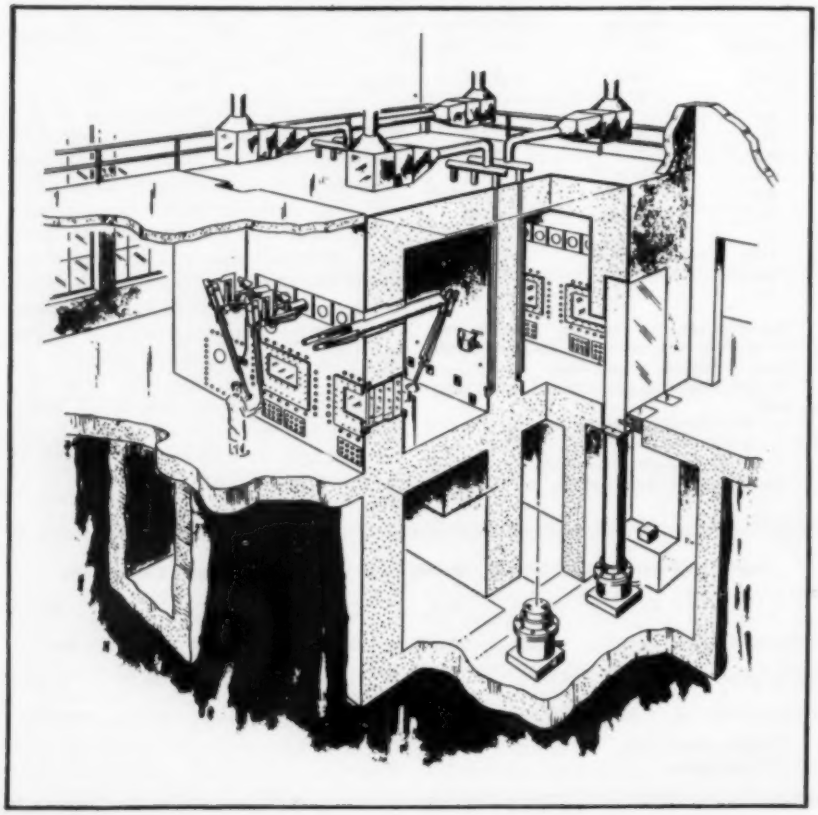
Various fluorinating procedures which have been developed enable dissolution of an imposing number of contemplated reactor fuels. It is anticipated that this will result ultimately in extensive applications of fractional-distillation methods for fuel reprocessing.

The direct distillation of molten, irradiated uranium to recover and concentrate plutonium will be reviewed under Pyrometallurgical Processes.

Pyrometallurgical Processes

The development of high power-density reactors and high burn-up fuels may aggravate the problems of spent fuel reprocessing. Conventional methods may require extended "cooling" periods of the fuel prior to reprocessing in order to avoid deleterious irradiation effects. Therefore, research and development work on pyrometallurgical, or so-called high temperature, processes has been undertaken in an effort to find a suitable way of processing short-cooled, highly irradiated fuels. These methods would enable heterogeneous reactor fuels to be processed with some of the advantages that accrue with continuous processing of aqueous homogeneous reactor fuels. They may also have possibilities for use in preceding more conventional processing for purposes of initial bulk reduction of radioactivity levels or crude concentration of fission-able substances.

If the irradiated fertile and fissionable materials can be processed as molten metals, not only would the above



The cutaway sketch shows relationship of the two Battelle hot cells to their respective subterranean chambers. The lower chambers will be used for storage and for experiments with radioactive materials which do not need direct viewing. Both upper cells have a 12-ft. head clearance, and longer chemical columns can be extended through holes into the subterranean chambers. Hydraulic rams at the right end of the cells raise and lower the two steel doors weighing 13 and 20 tons each. Above the cells is a ventilation and air-purification system.

fission-product separation

aims be realized but some other benefits may be obtained. Since the pyrometallurgical schemes avoid bulk chemical conversion during purification, the usual need for converting uranium or plutonium salts back to metal would be avoided. The purified material as obtained is ready for fabrication into new fuel elements. Variations in fuel alloy compositions which sometimes cause difficulties in aqueous processing systems may be of much less concern in pyrometallurgical processes. Finally, the fission products are isolated in a very compact form and, therefore, are more likely to be suitable for utilization or disposal. The principal objectives of these processes are otherwise similar to those of other types of processes.

The development of pyrometallurgical processes has been along two lines. One of these is concerned with reactor-blanket processing and the other with reactor-core processing. It is not anticipated that these would give more than partial decontamination. Thus, after many recycles with pyrometallurgical processing, special treatments may be necessary to remove at least some fraction of the elements which have not been removed. The pyrometallurgical operations, however, must be able to concentrate fissionable substances from blanket material and satisfactorily remove from core material those fission products which have high cross section or interfere with the fabrication qualities of the fuel.

The *three types of pyrometallurgical operations* which have received the most attention for blanket processing to concentrate plutonium are: (1) distillation, (2) salt extraction, and (3) molten metal extraction. Thermodynamic evaluations and experimental demonstrations have been conducted with encouraging results; however, the engineering feasibility and the economic advantages have yet to be determined.

Plutonium can be concentrated by *vacuum distillation* from molten uranium at 1,500-1,800° C. More than 99% removal has been effected and the experimental results agree with theoretical calculations. Table 7 contains the results of two typical runs. The two major problems are the materials of construction and the design of the plutonium collectors.

The *salt extraction* of plutonium from molten uranium has been successfully accomplished with halides such as UF_4 or $MgCl_2$. The distribution of plutonium in the system molten UF_4-molten uranium metal is such that, at equal weight rates of salt to metal, 90% of the plutonium goes into the salt phase. By repeating the extraction, it should be possible to obtain all the plutonium from the uranium. Although in this procedure the uranium remains in its metallic state, the plutonium is recovered as the fluoride or chloride and later must be reduced to metal.

Extraction with fused salts is also being developed for purification of the fuel from liquid metal homogeneous reactors. If the spent molten fuel such as uranium in liquid bismuth is contacted with a molten salt mixture, it has been found that most of the rare earth fission products are transferred into the salt phase.

A large fraction of the fission products, which are important from the cross-sectional standpoint in a thermal reactor, is removed in this way.

The third method under examination is the *use of molten metals as extractants*. Both silver and magnesium are immiscible with molten uranium and have favorable capacities for plutonium extraction. The plutonium distribution ratios (by weight) are about 2.0 for either the magnesium or silver system. Results in Table 8 indicate that the fraction of plutonium extracted by magnesium is independent of plutonium concentration, at least over a 300-fold range. When magnesium is used, the extraction-step operation must take into account the high-vapor pressure of magnesium at the melting temperature of uranium. When silver is used, the subsequent separation of plutonium from silver is a difficult one. At present, distillation of the silver is the preferred method for its removal.

These molten metal solvent extractions recover plutonium but are not highly selective insofar as separation of uranium or plutonium from fission products is concerned. This is illustrated by the data in Table 9.

A smaller amount of effort has been expended on a *continuous recrystallization or zone melting* process for purification, but the results are not encouraging. In order to realize the theoretical separations factors, it has been necessary to process at extremely slow rates (less than 1/250 linear in./hr.).

In the recycle of fuel from heterogeneous reactor cores, the primary objective is the removal of fission products. There is no real need to separate the uranium from the plutonium when reprocessing the core. To accomplish purification of core material, two different approaches are being studied. One is by *oxidative slagging* and the other by electrorefining. If spent fuel is melted in the presence of a limited amount of oxygen, the most stable oxides are formed preferentially. They are the oxides of cerium and rare earths. Upon liquation, these oxides float to the surface and may be skimmed off. As in all other pyrometallurgical operations, the rare gases and the halogens bubble off and are vented during the melting

Table 6.—Decontamination by Fractional-Distillation Method (irradiated uranium dissolved in ClF_3-HF)

	Decontamination Factors	
	Beta	Gamma
Evaporation from dissolver solution	about 10^4 to 10^5	—
Fractional distillation of above overhead	about 10^2 to 10^3	10^3
Over-all for both operations	about 10^7	10^7

Table 7.—Vacuum Volatilization of Plutonium from Molten Uranium

Temperature ° C.	Area sq.cm./g.	Time min.	% Volatilized
1680	0.7	40	91
1680	0.4	140	99

Table 8.—Plutonium Extraction in Molten System, Uranium-Magnesium

Pu Concentration in Irradiated U, p.p.m.	Weight Ratio U/Mg	% Pu in Mg Phase
0.3	1.0	60
23	0.9	60
55	0.7	71
97	1.0	67

Table 9.—Extraction of Irradiated Uranium with Silver

Element	% Extracted by Silver [a]
Cs	96
Sr	94
La	89
Ce	86
Zr	73
Pu	65

[a] Equal weight ratios of silver and uranium employed.

of the fuel. The fission products of intermediate volatility (cesium, strontium, lanthanum, and barium) diffuse into the crucible and through the slag layer. The oxygen needed for the slagging operation is supplied by the use of oxide crucibles, by control of the furnace atmosphere, or by the addition of oxides directly to the melt. Representative data from a typical run are shown in Table 10. Other substances, such as graphite, may be added to improve removal of zirconium and some of the other fission products. From Table 10 it will be noted that only ruthenium is not affected. Other noble metal fission products and niobium and molybdenum probably behave like ruthenium.

The second approach to fission-product removal for core processing is *electrorefining*. If the heavy metals are transported through a molten bath of alkali or alkaline earth halides (mixtures of chlorides or fluorides), the noble metal-fission products collect as an anode sludge. The rare gases are vented off at the anode. The active metal-fission products tend to build up in the salt bath. As a result of this build-up, the bath must be replaced or separately processed to keep the decontamination factors high. In most of this work to date, it has been convenient to use as a cathode some metal that forms a low-melting alloy with uranium so that the product can be continuously removed from the cell as a liquid. On small-scale runs, the material recovered at the cathode represents 98% of the metal leaving the anode and decontamination factors of 100 to 300 have been obtained for cesium, strontium, zirconium, and ruthenium.

Of all the pyrometallurgical processes, electrorefining is the only one that separates the bulk of the noble metals from the uranium.

Another solution to the core-processing problem may be the use of a scheme similar to the *deBoer process*. Uranium is iodized and then reclaimed as metal by hot wire (or tube) decomposition of the volatile UI_4. The only fission products that appear to transfer appreciably with the uranium are zirconium and niobium. However, cold trap arrangements can be used to effect better separation of zirconium and niobium iodides from the uranium iodide. The fate of plutonium has not yet been determined. Another application of the deBoer method which appears promising is the separation of U^{233} from irradiated thorium.

Experimental results obtained to date are encouraging for the development of one or more high-temperature processes suitable for short-cooled, highly irradiated fuels. However, the problem of equipment development is quite formidable and has yet to be completely resolved.

Some alleviation of the crucible problem is expected through the use of a lower temperature system than that of pure molten uranium; that is, small additions of certain metals will be employed to lower the melt temperatures. In addition, although the decontamination factors obtained are quite adequate from a reactor standpoint, they are not sufficient to enable direct fabrication of the fuel elements. Therefore, the problems of remote-control fabrication must be simultaneously solved to realize the advantages offered by pyrometallurgical processes. The recycle of many types of fuel eventually produces an accumulation of enough uranium or thorium isotopes and other transuranic elements so as to require at least some remote fuel fabrication. Therefore, one must be careful in cost estimates not to overpenalize the pyrometallurgical processes for their modest decontamination factors.

Table 10.—Oxidative Slagging

Element	% of original amount remaining in purified metal ingot [a]
Uranium	94
Plutonium	94
Cesium	0.1
Rare Earths	1.0
Zirconium	34
Ruthenium	95
Strontium	0.02

[a] 4 hr. at 1,200° C. in an oxide crucible.

fission-product separation

A PILOT PLANT FOR RECOVERY OF FISSION PRODUCTS

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U.N.–A/Conf. 8/P/317

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Industrial utilization of the gamma radiation from fission products requires compact sources of high specific activity. The starting point for the preparation of such sources will be the process waste streams from fuel reprocessing plants. These streams usually will be solutions of gross fission products mixed with inactive chemicals. From such solutions the problem of preparing a source of a specific fission product will involve the development of chemical separation processes and equipment to handle the material safely. Although the chemical process will vary depending on which fission product is to be concentrated, many design and equipment problems will be common to all processes.

The pilot plant described here produced kilocurie sources of solid carrier-free material.

The Process

The process which was developed for the separation of the specific fission product was divided into two phases: (1) isolation of the desired fission product from other fission products and from nonradioactive chemicals, and (2) concentration and conversion of the isolated fission product to a solid.

Isolation was accomplished by adsorption from a prepared feed in a packed column. The isolated fission product was eluted from the column and concentrated by precipitation in the presence of a cellulose filter-aid. The precipitate then was filtered, washed, and dried. The filter-aid was removed by combustion, after which the temperature was raised to about 650° C. to calcine the product.

Design Concepts

Five concepts guided the design:

1. COMPARTMENTALIZATION

Equipment which might require maintenance or which would be difficult to decontaminate, such as valves and pumps, was isolated.

2. GRAVITY FLOW

To minimize the possibility of backup of radioactive solutions into operating areas, all radio-

fission-product separation

active equipment was located in a lower cell called the process cell, and all operations were performed from above. To avoid holdup of solution, there were no loops in lines within the process cell.

3. CLEAN LAYOUT

To simplify maintenance, equipment was laid out in rows and the piping was installed parallel to the cell walls.

4. CONTAMINATION CONFINEMENT

To minimize the spread of contamination in the event of leakage of radioactive solution, major components were confined in sheet metal boxes.

5. MINIMUM MOVEMENT OF SOLID

To minimize the material-handling problem, several steps of the concentration process were carried out within a product vessel contained in a shielded cask.

Layout

The pilot plant was located in an existing two-floor cell containing obsolete but uncontaminated equipment. As shown in Figure 1, this cell was divided into three areas: an operating room, a sample room, and a process cell.

The operating and sample rooms were separated by a control panel which also acted as a contamination barrier. Instruments which might become contaminated owing to backup of radioactive solution were located on the sample room side of the panel board and were viewed from the operating room through sliding plate-glass windows. The floor of the sample room was lower than that of the operating room and drained to a sump in the lower cell. The floor was sheathed with stainless steel sheet for ease of decontamination.

The process cell contains all the process vessels. These were located in an open-top stainless steel box to prevent the spread of contamination in the event of leakage; sprays and steam were provided for decontamination. Also located within the process cell was the product-handling equipment. This included a narrow-gauge track on which an electrically driven transfer cart could be moved into and out of the cell.

Magnetite concrete blocks were added to the original concrete walls to provide sufficient shielding. Since the upper level was to be used for operations, it was necessary to shield the floor of this area from the lower level. Magnetite blocks were laid on the existing floor to a depth of 20 in.; a concrete cap was added providing a total floor thickness of 35 in.

Equipment

Chemical process pilot plants, by their nature, require valves, pumps, and sampling equipment. Where the final product is a solid, material-handling equipment must be included. The high levels of radioactivity associated with fission products are the major consideration in designing these components. Equipment must be as nearly mainte-

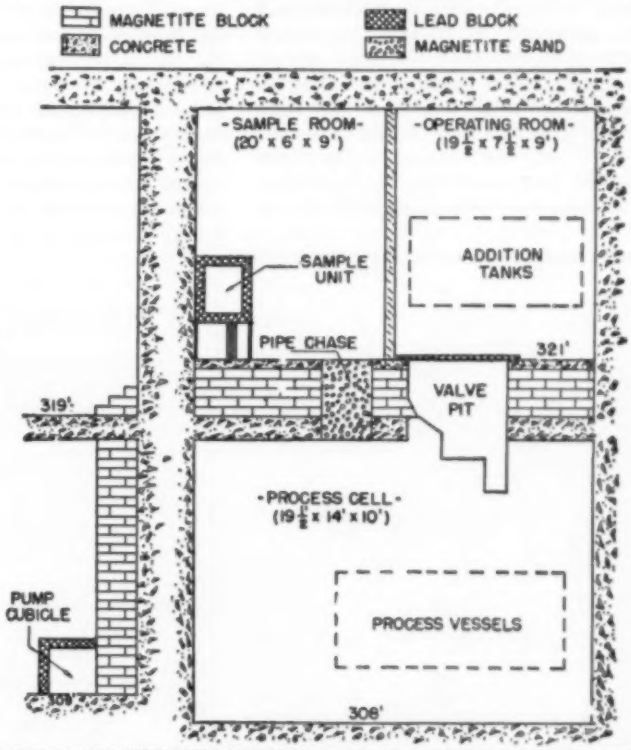

Fig. 1. Cross section of fission product pilot plant.

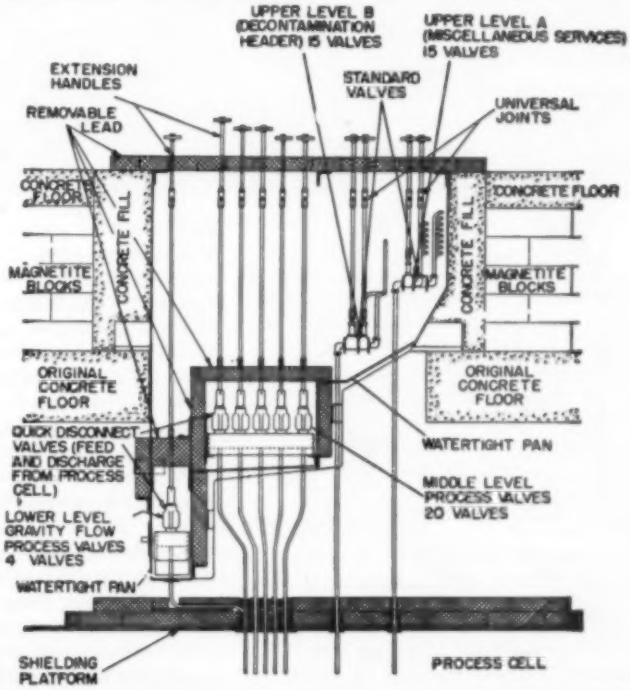

Fig. 2. Valve pit.

nance-free as possible, and where this cannot be guaranteed, the particular component must be made reasonably accessible. In order to achieve this accessibility, the various components were compartmentalized as described below.

1. VALVE PIT

Valves usually require maintenance. If possible they should be accessible and easily replaced. With lead shielding it was possible to create what was essentially a cell within the floor of the operating room. In this cell called the valve pit, all valves were located through which passed radioactive fluids and all valves carrying nonradioactive solutions to the process vessels. To prevent the spread of contamination in case of leakage, the valve-pit container, as shown in Figure 2, was an open-top water-tight vessel.

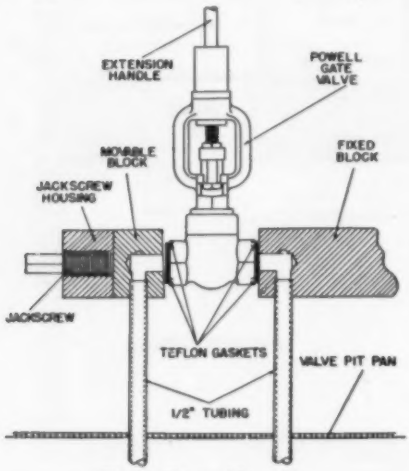

Fig. 3. Removable valve.

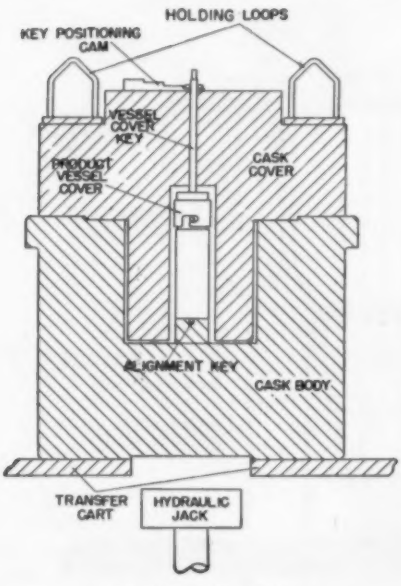

Fig. 4. Product cask.

There were three levels of valves in the valve pit. Valves in the upper level were used to feed nonradioactive solutions from the operating room into tanks in the process cell, and the flow through them was downward. These valves were installed with regular tubing and fittings. Two inches of lead shielding in the form of lead blocks, which covered the top of the valve pit, protected the operators against the slight possibility of accidental backup of radioactive solutions through the lines to these valves. In the middle level valves and lines were located through which ran process solutions or through which the process tanks were connected to the pilot plant vent system. Flow through these valves was from below into the valves and down into the process cell. These valves were shielded by an additional 2 in. of lead in the form of lead blocks. The process valves which required gravity flow from one piece of process equipment to another were located in the lower level. As seen in Figure 2 the lower-level valves were located below the ceiling of the bottom cell. These valves were to carry the most highly radioactive solutions and were shielded by an additional 4-in. thickness of individually removable lead blocks.

Valves in the middle and lower levels were stainless steel gate valves of slightly modified standard design. For quick removal each valve of the lower two levels was installed between two smooth-faced stainless steel blocks, one fixed and one movable (Figure 3). Teflon gaskets were inserted into recesses in the end faces of these valves. The valve seal was made by forcing the movable block closer to the fixed block, thus compressing the gaskets. This was accomplished by a single large diameter screw.

Use of comparatively small pieces of lead shielding eliminated the necessity of decontaminating the entire valve system. To replace a valve, it was necessary to decontaminate only one row of valves and remove the lead shielding blocks over the row of valves and the row of jack screws. A faulty valve could be released by backing off the jack screw by a long-handled ratchet wrench; the valve was then removed with a hook. A new valve could be installed by reversing the above procedure. To avoid radiation from the tanks in the lower cell when part of the lead was removed from the valve pit, a 2 to 4-in. thick shadow shield of lead was located on a platform in the lower cell directly under the valve pit.

All the valves were operated by extension handles protruding through the shielding to the operating floor. Universal joints were used in these extension handles to take care of any misalignment of holes in the lead shielding. No radiation leakage through these holes was detected.

2. PROCESS PUMP AND PUMP CUBICLE

A diaphragm pump was used to feed the adsorption column at controlled flow rates. This pump had a hydraulically driven diaphragm which in turn was coupled hydraulically to two remote diaphragm heads, either one of which could be operated independently. The heads and the process lines leading to and from them were contained in a lead-shielded stainless steel box (the pump cubicle) located outside the wall of the process cell. To avoid holdup of liquid, care was taken in designing the pump cubicle piping in order that the flow from the feed make-up tank was downward to the bottom of the pump and upward from there to the column. The valves for isolating the remote heads from each other were of the same type as those used in the valve pit and were installed in a similar way.

3. CONCENTRATION EQUIPMENT

For mechanical simplicity and to minimize the movement of solids, the concentration operations were carried out in a product vessel which was located within the product cask during the entire sequence of operations. These operations included filtration, drying, washing, combustion, and calcination. As shown in Figure 4, the product cask consisted of two basic parts, a body and a cover. The cover was constructed so that a large hole was left in the body when the cover was removed. The product vessel was keyed to a pedestal welded to the cask at the bottom of the hole. The cask body was positioned by dowel pins on the transfer cart on which it was moved into the process cell.

A cover removal station and a processing station were located within the process cell (see Figure 5). At each of these stations there was a hydraulic jack which raised the cask from the cart. After the cask cover was removed at the first station, the cart was moved to the processing station where the hydraulic jack raised the cask and sealed the product vessel against a fixed flange. The product vessel was a double-walled vessel, with the inner wall made of a sintered stainless steel filter. There were two openings in the top of the product vessel: (a) through one, the slurry of precipitate and filter-aid entered the filter element and (b) through the other, the filtrate was discharged by way of a tube connected to the annulus between the filter

element and the outside wall of the vessel. A spiral-wound asbestos and stainless steel gasket selected for its ability to withstand high temperatures was centered over each hole and tack-welded to the top of the product vessel. These gaskets were used to seal the product vessel against the fixed flange and also to seal the product-vessel cover to the body of the product vessel after operations were completed (Figure 6).

Suspended from the fixed flange was a cylindrical electric resistance open-end furnace. This furnace was used to dry the filter cake, to burn the cellulose filter-aid, and to calcine the product. Surrounding the furnace was a stainless steel can containing thermal insulation, which fitted inside the hole of the cask body.

After the operations were completed, the cask containing the product vessel was lowered from the fixed flange and returned to the cover station where the cover was replaced on the cask. The product-vessel cover was locked and sealed in position after the cask was brought outside the process cell. The locking was accomplished by means of a key which extended through the cask cover.

4. PROCESS VENT SYSTEM

The off-gases from the combustion operation passed through the filter element into a filtrate receiver, and from there into the process vent system. The purposes of this vent system were (a) To prevent the spread of contamination, (b) To remove particulate matter which might be present in the off-gases not only from the filtrate vessel but also from all the other process vessels, and (c) To maintain a slight vacuum in the process vessels. The blower for the vent system discharged into the building ventilation exhaust system, providing a large dilution before the exhaust gases passed to the building stack. An asbestos-paper filter was located in the process vent line and was installed between two spring-loaded flanges which could be sprung apart to permit quick replacement.

5. SAMPLING

It was desired to make sampling simple, safe, and reproducible. All radioactive solutions associated with the sampling operations were contained within a shielded stainless steel box called the sample unit. This box was divided into two cells, a sampling cell in which samples were drawn from the process tanks, and a sample-handling cell in which the samples were prepared for transfer to the analytical laboratory.

Both recirculating and noncirculating types of samplers were considered. The recirculating type gives good samples but results in the atomization and subsequent entrainment of appreciable quantities of radioactive solution. The problem with the noncirculating type is to obtain reproducible samples. It was decided that for the small volume of highly radioactive solution in the pilot plant, the entrainment would be the more serious problem. As a result, the noncirculating type was selected.

The samples were drawn by means of a hand- operated piston. The vacuum (Figure 7) created by pulling out the piston caused the liquid to flow from the tank below up into the sample unit. A surge pot was inserted in the line to prevent drawing of the sample solution into the unshielded piston chamber. Eight tanks could be sampled, each having its own piston and surge pot. The components of the sampling system and tanks were elevated with respect to each other in such a way that there was no holdup of solution in lines or equipment. This was a major factor in obtaining reproducible samples. Provision for flushing out the surge pots and sample lines was by funnels entering the surge pots.

With the sample line full of solution up to and partly into the surge pot, a sample was removed by means of a two-way valve located in the sample line between the tank and the surge pot. This valve was a stainless steel plug valve with a Teflon liner. The body of the valve had four openings, and the plug had a hole with a volume of ½ ml. After the sample was drawn, the plug was rotated 90 degrees and the sample was dropped into a small glass cone. The cone was held in a slide assembly on a monorail and was moved into the handling cell.

In the handling cell primary dilution for the analytical laboratory could be made, if necessary. In addition unused portions of samples were removed through a suction line connected by way of a trap and vacuum pump to a waste tank in the cell below. Decontamination sprays were provided in each of the two cells of the sample unit. The interior of the sample unit was observed through lead glass windows.

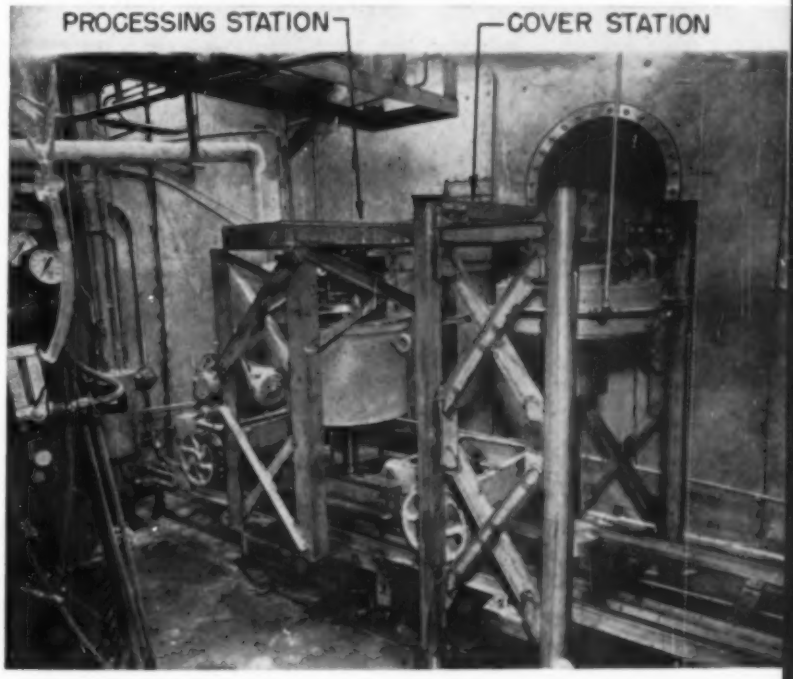

Fig. 5. Concentration equipment.

Summary

A review of the actual design shows how the design concepts were followed.

1. Compartmentalization

The chief example of this was the division of the pilot plant into three areas for processing, sampling, and operating. In addition, the major

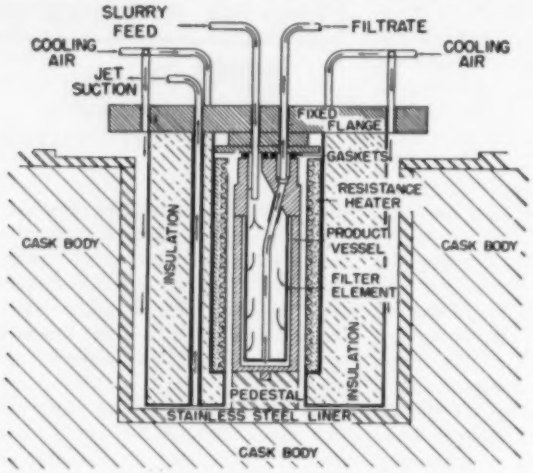

Fig. 6. Product vessel at processing station.

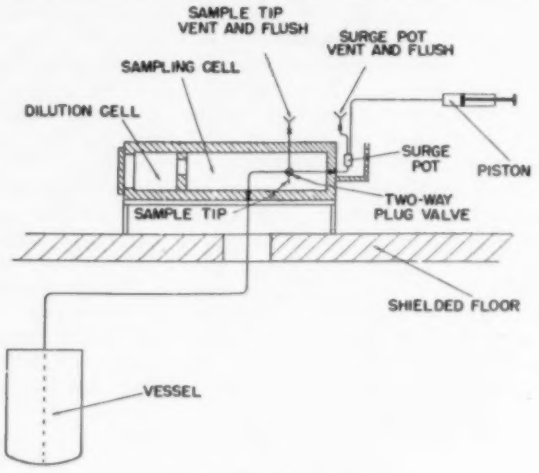

Fig. 7. Sampling system.

components, the process valves, the process pump, and the sample unit were further compartmentalized.

2. Gravity Flow

The location of the operating and sampling rooms above the process cell greatly reduced the possibility of radioactive solutions accidentally appearing in operating areas. Installation of piping without loops simplified decontamination and aided in obtaining reproducible samples.

3. Clean Layout

The installation of process cell equipment and piping in an accessible manner provided for ease of maintenance.

4. Contamination Confinement

The valve pit, pump cubicle, process vessel box, and the separation of the sample room from the operating room are all examples of the application of the principle of confining contamination.

5. Minimum Movement of Solids

Use of the product vessel for several processing steps while it was positioned within the product cask was an application of this concept.

In practice, the design concepts proved sound. The pilot plant was operated for a period of six months during which a number of successful kilocurie runs were made. Because of the short period of operation, some features designed into the pilot plant to aid in decontamination and maintenance were either not tested or tested only to a limited extent.

There was no apparent leakage through valve gaskets or packing or across valve seats. During subsequent modifications of the pilot plant for a different process, some of the valves in the valve pit were removed and replaced without difficulty.

The feed pump operated satisfactorily except during the last run when the two remote heads failed and a temporary feed system was used to complete the run. Because of the imminent termination of the project, the pump was not dismantled to determine the exact cause of the failure.

The concentration equipment gave no difficulty. The design of the product vessel proved adequate for the multiple processing steps and in the prevention of carry-over of activity to the process vent filter during combustion and calcination. The process vent filter was replaced once per run when the dose rate reached 100 mr./hr.

The sample unit provided a safe means for obtaining reproducible samples. The safety of this operation and of operation of the pilot plant as a whole is indicated by the fact that radiation exposures to personnel did not exceed the maximum allowable daily radiation dose of 50 mr./day, at any time.

It is believed that the concepts followed in the design of this pilot plant are applicable to most high-level radiochemical pilot plants.

radioactive wastes

the management and disposal of radioactive wastes

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U.N.–A/Conf. 8/P/310

Characteristics of Radioactive Wastes

LEVELS OF ACTIVITY

In general, *high-level* wastes (containing as much as 10^2 curies/l.), are those requiring extensive shielding to protect persons handling them from exposure to damaging radiation. It is difficult to estimate the percentage of total waste production which is of high-level activity because of the variety in kinds of wastes. They might be as low as 0.5 and as high as 50% depending upon the material being processed at a plant.

Intermediate-level wastes also require shielding and must be handled with much care. The *low-level* wastes are those which if decontaminated by a factor of 10^2 or 10^3 would approach

radioactive wastes

permissible limits for human exposure. The range of their activity would be from 10^{-4} to 10^{-3} microcuries/ml.

KINDS OF WASTES

Radioactive wastes may be in liquid, gaseous, solid state, or in some intermediate form. They may be combustible or noncombustible. Their kind and intensity are not detectable by human senses. These insidious characteristics make such wastes especially dangerous because they could be released to the air, the soil, or to surface waterways without detection. With proper instrumentation and radiometric analytical techniques, however, the constituents and characteristics of radioactive wastes may be determined with accuracy.

Important from the waste-disposal point of view are the long half-lives and known damaging properties to human tissues of certain of the isotopes. Regardless of what is done to or what use is made of a radioisotope, it will continue to give off radiation at its natural decay rate. As long as its radioactivity is in excess of permissible limits of exposure a radioisotope is a potential hazard to man.

These unique properties of radioactive wastes place more than average responsibility on those accountable for their disposal and also on officials charged with the protection of public health and natural resources.

Sources and Treatment of Radioactive Wastes

Radioactive waste products must be evaluated well before being treated and disposed of. This will be especially true as competitive industry expands its use of nuclear energy and determines the true cost of waste treatment and disposal. Current practices, while adequate, are costly and necessarily conservative. Special emphasis is being given to environmental problems in the disposal of these wastes, because as private industry uses atomic energy its plants must be reasonably near the populations they are to serve.

RAW MATERIALS

Every industry creates some waste in progress from raw material to finished product. In the atomic energy industry the levels of activity of radioactive wastes increase progressively as industrial processes move closer to fission action.

Ores & Reactor Fuels

The important raw materials for the moment are the radioactive ores of uranium. Radon, a product of radioactive decay of these ores, can cause serious harm. With good ventilation the level may be held to a minimum by methods familiar in other mining operations.

The progressive processing of the radioactive ores to the ultimate fuels results in considerable volumes of long-lived alpha-emitting wastes. Chemical sludges containing uranium and giving off radon are usually held in concrete storage basins. They are low in specific activity and generally represent no serious local hazard. Because of the long periods they will remain radioactive, they will continue to present a real problem in storage.

Latest General Electric atomic attire now in vogue at the huge plutonium-producing plant at Richland, Washington, operated by G. E. for AEC. Plastic, balloon-like suit provides protective barrier against radiation in "hot" areas and permits a man to determine extent of contamination and do clean-up and maintenance work in such areas. "Train" in rear is flexible plastic tunnel leading from suit to entrance port in wall. It provides air and serves as an entrance and exit passage. Air mask worn is used only if the suit becomes torn or punctured. Suit and tunnel remain inflated because air inside contaminated area is at a lower pressure than air on the outside. This pressure differential is maintained to assure that any flow of air will be into the contaminated area rather than out.

Fumes and Dusts

Fumes and dusts are removed by mechanical ventilating systems as near as possible to the source of production. The size, mass, and other characteristics of wastes in these feed-material operations vary widely. Specifications for air-cleaning equipment, therefore, must be much more rigid than in most industries.

COOLANTS FROM NUCLEAR REACTORS

When the fuel is irradiated by neutrons in reactors, tremendous amounts of heat are produced. Reactors may be cooled by air, water, liquid chemicals, or by other media with suitable fluid and heat-exchange properties. Since in the reactor core these media are exposed to neutrons, they become irradiated. The radioisotopes formed depend on the composition of the cooling media. The problem of disposal of the irradiated media varies, depending on volume, radioactivity level, and the suitability of local conditions for release of the coolant, without creating environmental hazards.

Air

In an air-cooled reactor, such as the one at the Brookhaven National Laboratory, the coolant flow through the reactor is at a rate of 300,000 cu. ft./min. The air in this system is prefiltered to remove dusts which otherwise would become radioactive when passing through the reactor. Under the neutron bombardment of the air coolant, radioactive argon, xenon, and krypton are formed. The irradiated air is discharged to the atmosphere through a stack more than 300 ft. high. The dilution is normally such that the radioactivity is well below permissible limits in air breathed by humans. While the reactor is operating, the air around is monitored. Should permissible limits of radioactivity be exceeded, the power level of the reactor would be reduced or the unit would be shut down entirely. The results have been good.

Single-Pass Water

The Hanford reactors are cooled by a single pass of water from the Columbia River. The river water is purified by chemical coagulation, settling, and filtration in much the same way water is treated for public water-supply systems. During the first few hours after leaving the reactor the rate of decay of radioactivity in the cooling water is high.

The problem of ocean disposal is now

plored because it has obvious advan-

SPECIAL NUCLEAR ISSUE

Table 1.—Typical Reactor Fuel Processing Wastes
(high-level waste)

Characteristics

Gross beta activity	counts/(min.)/(ml.)	$1.6 \times 10^6 - 2.2 \times 10^{10}$
Alpha activity	counts/(min.)/(ml.)	$6.0 \times 10^5 - 6.0 \times 10^8$

Radioactivity—1 to 4×10^8 curies/gal. (neutralized).
Effective life—about 600 yr.
Heat generation—1 to 3 B.t.u./(hr.)/(gal.)
Power equivalent: 1 g. U^{235} = 24,000 kwhr. (100% efficiency)
Fission product wastes: 1 g. U^{235} forms 1 g. fission products
Wastes from processing: 0.5 to 5.0 gal. waste solution/g. U^{235} consumed
Waste chemistry:

Ions	Concentration in moles/l.
Al	0.5–2.5
NO_3	2.0–8.0
H	0.5–3.0
Na	0.1–0.2
F	2.0–3.0
Z_r	0.3–0.6
SO_4	0.3–0.6

sp. gr.—1.1 to 1.4

Recirculated Water

Other types of reactors such as the Materials Testing Reactor (MTR) use closed cooling systems. In such it is customary to filter and to demineralize the coolant so that there will be little or no material in the water to become irradiated. Since this water must pass through pipes and equipment, it will eventually pick up some contamination due to corrosion, dissolving properties, or abrasion. In order to prevent any marked increase in radioactivity in such systems, a small percentage of the total flow is bled off, filtered, demineralized and then returned to the main stream. In other cases the bleed-off water is wasted. The waste water or the spent filter and demineralizing media eventually acquire radioactivity and are disposed of usually by land burial.

OTHER REACTOR WASTE PROBLEMS

When a reactor is disassembled or parts which have become irradiated are removed a problem in disposal of the first order is presented. Extraordinary care is given to shield workers and the time and amount of their exposure are rigidly controlled. Highly active material is held in a designated fenced-off area or is buried in a burial ground with adequate cover to shield against surface exposure. An inventory of buried radioactive materials is maintained.

CHEMICAL PROCESSING

The high-level wastes originate principally from the chemical processing of reactor fuel. Associated with the irradiated fuel are many fission products with radioactive half-lives varying from seconds to millions of years. Such products have fixed rates of radioactive decay which never vary. Customarily the irradiated fuels as removed from a reactor are stored under water in order to permit decay of the short-lived fission products. Storage from 90 to 120 days is desirable, but processing within shorter periods may be necessary. With shorter periods of storage, problems of handling and disposing of the product are intensified.

These high-level wastes contain the entire spectrum of fission products formed when the uranium atoms are split. The waste solutions contain various salts and acids besides the fission products. The manner in which the uranium is utilized in the reactor, whether in solid or liquid form, determines the chemical separations processes used; likewise it determines the physical, chemical, and radiochemical properties of the waste solutions ensuing. Characteristics of typical reactor fuel processing wastes to be expected are shown in Table 1.

Significant Isotopes

Of special significance because of half-life or radiotoxicity in disposal of atomic energy wastes from chemical processing, are the isotopes shown in Table 2.

Concentration

Improvements have been consistently made in the dissolving, extraction, and stripping processes and facilities. Most important is the effort to remove these highly active wastes at the point of origin—where the volume is small—rather than to permit them to mix with and contaminate a high-volume system where decontamination is very expensive.

Storage Underground in Tanks

Storage of highly radioactive wastes in large underground steel and steel-and-concrete tanks as currently practiced presents a real problem. The capital cost varies from $0.35 to $2.00/gal. of capacity. The thermal heat which results from gamma radiation is very high. In order to protect the tanks from deterioration by corrosion, excess heat must be carried away by a cooling system. To detect leakage from these tanks, a system of drains is installed around them leading to a monitoring pit. The true life of these tanks is unknown. It is certainly much shorter than the length of time some of the long-lived radioactive materials will continue to be hazardous. It is not a simple task to remove entirely the high-level radioactive material after it has been stored in a tank over an extended period. Steam jetting is one method in use.

Environmental Considerations

Environmental factors, such as the capacity of soils in the vicinity of these tanks to absorb radioactive wastes should they leak, and the rate of movement of such wastes through the soils, especially to underground sources of water supply, are extremely important and are being studied. Also under study is the fixing of high-level radioactivity in wastes by natural or prepared soils or by chemical compounds so that they may be disposed of safely by burial or underground storage with little likelihood of release to the environment. Removal of the more hazardous and long-lived radioisotopes such as Sr^{90}, Cs^{137}, and Ce^{144} before discharge to the tanks or to the soils would reduce environmental hazards, provided they were adequately fixed or retained for disposal.

Ultimate Disposal

At Brookhaven a method of absorbing high-level fission products in specially prepared and extruded montmorillonite clay pellets is at the pilot-scale stage of development. These pellets are then subjected to high temperature (800°-1,000° C.) in a kiln to form hard ceramic beads from which the radioactive material cannot be leached. Waste so treated could be placed in the ground or be stored in suitably shielded places with assurance of insignificant release to the environment. The process has some possibilities as a method of providing radioactive sources from wastes.

Ranges of costs of some of the methods discussed above are shown in Table 3.

Ocean Disposal

Proposals have been made that high-level radioactive wastes be disposed of by dumping into the oceans far off shore, as is now practiced for disposal of some industrial wastes. The cost of shielding and transportation militates against this method for high-level wastes for many present and future plant locations. Other doubtful factors are the high levels of radioactivity and heat in these wastes, the inability of recovery and uncertainties as to the effect of these wastes on other uses of the oceans in the service of mankind.

radioactive wastes

The problem of ocean disposal is now under study at Johns Hopkins. In the meantime the practice to withhold such materials will be continued by the AEC.

MISCELLANEOUS WASTES

Normal residual-waste products of atomic industry such as litter, dusts, chips, paper, wipes, clothing, obsolete material, and equipment furnishings, as well as structural material from plant renovation or wrecking are segregated usually in special containers at the plants. They are monitored then for the kind and level of activity. Material contaminated by short-lived radioactivity may be stored for decay and then be disposed of normally. Where the half-life of the radioisotope is long, the problem is complicated and still unsolved.

Incinerators

Combustible radioactive material such as paper, wipes, animal carcasses, and bedding material for animals, pieces of wood or cardboard may be disposed of by incineration. Incinerators have been built and provided with equipment for a high degree of clean-up of the products of combustion resulting in radioactive solutions to be disposed of as well as the incinerator ash. One of these (Argonne) has performed satisfactorily at relatively high costs of $2.68/cu.ft., including overhead and amortization charges.

Baling

At Knolls Laboratory wastes of the kind formerly incinerated are now being baled with the use of an electric baler. The bales are stored uniformly and then shipped by rail to a storage area operated by the AEC in a part of the old Lake Ontario Works near Youngstown, N. Y. Here the bales are stored along with certain radioactive sludges and miscellaneous obsolete equipment and material which cannot be reclaimed or salvaged for scrap because of radioactivity.

Burial

Burial of radioactive wastes, particularly solids, is widely practiced at the larger AEC installations such as Hanford, Oak Ridge, the National Reactor Testing Station, and at Los Alamos. The selection of burial grounds is made with careful attention to factors listed under "environmental considerations."

Deep Wells

Consideration also has been given to the possibility of disposal radioactive-waste solutions by discharge to abandoned oil and gas domes through deep wells. The economic aspects of the problem rest on the cost of shielding and delivery to the chosen well site. This method of disposal is being explored because it has obvious advantages. The feasibility of the use of abandoned mines and caves as storage places for high-level radioactive wastes also is being considered.

Laundry Wastes

Formerly, evaporation of the wastes from laundering protective clothing was common practice, but usually the levels of activity were not sufficiently high to justify this expensive treatment. Such wastes may be mixed with the domestic sewage. About 90% of the radioactivity is found in the dried sewage sludge and the remainder in the effluent which is discharged to the ground. At Los Alamos, laundry wastes containing plutonium have been decontaminated by a coprecipitation method.

Radioisotopes

Of the radioisotopes the AEC manufactures and sells, the most widely used are P^{32}, I^{131}, C^{14}, Na^{24}, and Au^{198}. The levels of activity used are such that, in general, waste disposal is not a serious problem; current practice is to discharge radioactive wastes to one or more holding tanks. They are monitored periodically and if activity is at or below a prescribed level the contents are released, usually to a public sewer system; otherwise they are held for decay to the prescribed levels for release. At places where flow in the sewers is adequate to give the desired dilution to safe levels, direct discharge without holding is practiced.

Future Problems

The disposal of reactor and fuel-processing wastes will be one of the major controlling factors in determining the extent of the use of power reactors competitively with other sources of fuel for energy production. The resulting total fission products on hand to plague the operator and regulatory agency will be prodigious. To dispose of these materials will undoubtedly challenge the ingenuity and imagination of the scientist and industrialist.

Some general indication of the magnitude of these prospective accumulations of radioactive materials with an assumed nuclear power production over the years may be obtained from the following calculations.

Assuming that by the year 2000 the United States population will double, the per capita consumption will triple, and 10% of the increase in electric energy produced will be generated by atomic reactors, then the nuclear power would be 2.2×10^{11} kwhr./yr.

One gram of U^{235} will furnish approximately 24,000 kwhr. and will produce about 1 g. fission products. At 25% heat to power efficiency, the nuclear reactors would produce 3.67×10^7 g. fission products/yr., which is equal to 83,000 lb. or approximately 41 tons/yr.

Under current processing techniques these fission products are dissolved or suspended in liquids. Depending on the type of reactor and the chemical separations process employed, the liquid vol-

Table 2

Radioisotope	Mass number	Atomic number	Half-life
Cesium	137	55	33.0 years
Strontium	90	38	19.9 years
Strontium	89	38	53 days
Iodine	131	53	8.1 days
Niobium	95	41	35 days
Cerium-Praseodymium	144	58–59	280 days
Yttrium	91	39	61 days
Barium	140	56	12.8 days
Zirconium	95	40	65 days

Table 3.—Range of Costs [a] of Treatment and Disposal Methods

	High-Level Wastes	Low-Level Wastes
Tank storage	$0.37 to $2.00/gal.	
Evaporation	$0.14 to $0.71/gal.	
Land burial	limited practice	$0.14 to $2.00/cu.ft.
Sea burial	not practiced	approx. $10.00/cu.ft.
Land transport	[b]	

[a] All costs include interest, depreciation, and overhead.

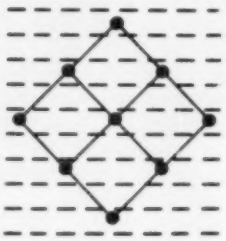
[b] Land transportation commonly costs about 4 cents/ton mile. However, in transporting high-level wastes under ICC regulations, about 95 to 99% of tonnage shipped is shielding which makes this item relatively costly.

generally reform, and the disruption is after several years' operation there is

umes may measure as little as 0.5 gal./g. U^{235} or as much as 5 gal./g. U^{235} for unneutralized waste. The gallons of waste expected then would be about 1.8×10^7 to 18×10^7 gal./yr., or roughly 50,000 to 500,000 gal./day.

One hundred days after removal from the reactor, the radioactivity of these fission products will be approximately 800 curies/g. The half-lives of the radioactive fission products of any consequence vary from minutes or less for isotopes such as Pr^{146} and Ce^{146} to 33 years for Cs^{137} and 20 years for Sr^{90}. It would take about 600 years for the latter two isotopes to decay to the concentrations allowable in drinking water, assuming no evaporation or dilution.

radiation uses



CHEMICAL PROCESSING IN INTENSE RADIATION FIELDS

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The types of radiation effects encountered in chemical processing, and the result of these effects on limiting the radiation level for six common separation steps, are described.

Introduction

Utilization of atomic energy depends upon chemical operation at every stage—fuel preparation, reactor control, fuel reprocessing, fission product separation, waste processing and disposal. Some of these operations involve treatment of highly radioactive materials. Reactors of high specific power also require fuel and waste processing at high-radioactivity levels since inventory charges and storage-facility costs make it difficult to justify long-cooling periods. Both of these incentives—demand, for pure fission products and economic pressure on reactor operating costs—may be expected to increase the trend toward chemical processing at the highest possible radiation intensities.

From the economic standpoint, the handling of radioactive materials may be expected to become considerably cheaper, both from the usual lowering of costs as volume is increased, and from the effects of fuller understanding, more efficient and less "over-safe" designs, and routine operation. This cost lowering will be accentuated by two effects: (1) the logarithmic effect of shielding, so that, for example, if 5 ft. of concrete are needed for 1,000 curies, 6 ft. are good for 10,000 and 7 ft. for 100,000, and (2) the better understanding of hot chemical processing will enable higher specific activities to be used, permitting the larger quantities to be handled in smaller plants. Thus, whereas processing at low-radiation intensities is much simpler and well understood, we find that economic considerations and in some cases technical requirements insist that processing be done at the highest possible intensity.

Within the last few years several varied types of chemical operations have been carried out in the United States at high radiation levels. It is the purpose of this paper to summarize this experience, to indicate the limiting effects of radiation intensity, if any, on various types of chemical operations.

DOSE UNITS

In order to discuss the radiation sensitivity of various processes, some unit of measurement for radiation energy and energy-density must be adopted. Such units as roentgens per hour per cubic centimeter and curies per gram have been widely used. However, a convenient unit for high intensity work is the watt-hour per gram. This unit may be related to others as follows:

1 watt-hour per gram $= 2.25 \times 10^{25}$ e.v./g.
$= 169$ curie-hr./(g.)/(Mev decay-energy)
$= 4.34 \times 10^5$ roentgen (air)
$= 3.74 \times 10^{-4}$ g. moles/unit G value/g. (unit G value is one molecule converted/100 e.v. absorbed energy)

General Observations

It may be generally concluded from experience that effects of radiation are surprisingly small in number and influence. Chemical reactions for the most part proceed with utter indifference to the radiation. From the recent advances in understanding of radiation chemistry the effects which are observed can be readily explained, and it should now be possible to predict what radiation effects would be likely for any proposed chemical operation.

As is well known, the result of the absorption of ionizing radiation in molecular material is the breaking of chemical bonds and the forming of free radicals, ions, excited molecules, and, in solids, lattice vacancies or "holes." In dilute solutions most of the energy is absorbed by the solvent, and the primary products formed are characteristic of the solvent rather than of the solute. For water, these are H and OH free radicals, H_2O_2, and H_2 gas. In other substances the products are of course determined by the composition. The influence of the particular type of ionizing particle on the products formed has been widely studied and found to be one of degree rather than kind.

OXIDATION REDUCTION

The products formed in irradiated material contain equal amounts of potential oxidizing and reducing substances. These can react with any substance present which is capable of oxidation or reduction *provided the oxidized or reduced form is stable in the existing environment.*

Thus, ceric sulfate solution, ordinarily quite stable, suffers reduction to the cerous state when irradiated. Ceric ion would not be reduced, however, in the presence of persulfate ion, since it would be immediately reoxidized, and the net result would be destruction of persulfate. Chromate solutions suffer reduction by radiation, but large-scale runs on radioactive barium at high intensity have been made, precipitating the barium quantitatively as the chromate. The precipitate remains stable as long as it is mixed with the mother liquor, even though the excess chromate in the solution is being slowly reduced. But if the precipitate is filtered and washed, no excess reagent remains, and the barium is rendered soluble as the chromate is reduced without replacement.

The conclusion to be emphasized is that although radiation provides energy and local oxidizing and reducing effects, these effects cancel unless a more stable form results in one direction than in the other or unless the reaction is irreversible. The high susceptibility of organic compounds to radiation damage is thus understood. The bonds broken will not

generally reform, and the disruption is irreversible.

The action of radiation as a promoter of only those oxidation and reduction reactions which are compatible with the environment corresponds to that of a catalytic rather than chemical agent. But its nature is that of a consumable catalyst, since the effect cannot exceed the amount corresponding to the radiation absorbed. Thus the time of exposure and the geometry of the equipment become important factors. If a sensitive precipitate which is not itself the main source of radioactivity can be quickly formed and removed from the bulk of the solution, a large portion of the radiation attack may be avoided and a successful result obtained. A protective effect can be obtained also by addition of a more sensitive material than the one which it is desired to isolate.

GAS EVOLUTION

In substances in which a stable gas phase can exist upon molecular disruption, gas formation will usually be a result of irradiation. In addition to the chemical changes, gas formation may influence the success of a chemical separation process by profound physical effects such as stirring the solution, disrupting precipitates, sweeping volatile reagents out of solution, plugging filters and resin beds, etc.

In the phenomenon of gas evolution lies one of the principal differences in the behavior of different kinds of ionizing radiation. In pure water alpha particles and fission fragments produce mostly molecular hydrogen and hydrogen peroxide, and beta and gamma rays produce a preponderance of free radicals, which tend to recombine.

Thus, water-moderated reactors having solid fuel elements experience almost no radiolytic gas formation (if the water is pure), while homogeneous reactors with aqueous solutions must contend with large quantities of explosive off-gas mixed with highly radioactive fission gases. Thus, a remote-control chemical problem at high radiation intensity is created.

The homogeneous reactor work in the United States has led to three solutions to this problem: *One method* is to use a catalytic recombining apparatus containing usually platinized alumina pellets. The gas is conducted through the apparatus at high temperature and the resulting water is condensed and returned to the reactor. A *second method* makes use of small quantities of copper ion dissolved in the reactor solution. If the solution is operated at about 300° C. or above, the radiolytic gas is combined internally. The *third approach* consists of operating the reactor at such a temperature that the thermal recombination rate, assisted by the catalytic effect of uranium ion, is sufficient to control the gas formation.

Only the first method described constitutes a real processing operation since the other methods essentially remove the problem. It can only be reported that after several years' operation there is no observable effect of the intense radiation field (0.1 w./cc. gas) upon the catalyst bed.

PEPTIZATION

The peptization of solid precipitates may be related in some cases to gas formation within the crystal.

In the separation of Ba^{140} and La^{140}, a special technique was necessary in this case to prevent peptization. Radioactive lanthanum was first precipitated as oxalate, stirred long enough to allow crystal growth, and then converted to fluoride by adding hydrogen fluoride. The intermediate compound may have been an oxalatofluoride. Although the oxalate was itself rapidly destroyed by the radiation, it persisted long enough to form large crystals, and the resulting fluoride found itself in large pseudocrystalline masses with less water content than directly precipitated fluoride and therefore less gel-like in nature. It is believed that this agglomerate resisted dispersion and that the lowered water content decreased internal gas formation, thus accounting for the improved results.

HEATING EFFECTS

The absorption of radiation energy of course produces heat. In special cases, such as with plastics or other organic materials, problems may be encountered, but in general the quantities of heat produced in handling radioactive materials may be removed readily by standard means. Solution operations have been done at energy inputs of 0.4 w./g. (200,000 curies/l.) without special cooling troubles, and refractory solid precipitates have been handled at 500 w./g. (500,000 curies/cc.).

Heating effects are mentioned here, however, to point out that the self-heating may be turned to advantage in the process. One example is the evaporation of La^{140} solutions, where the external heat is turned off, and the radiation heat provides boiling without bumping and greatly speeds up the process. Another is the vacuum distillation of polonium, which provides its own heat to distill from an insulated surface to a cooled surface.

EFFECTS ON ORGANIC MATERIALS

The discovery of the cross-linking of polyethylene under irradiation seems to have resulted in an important commercial process, but similar effects have been observed in high-intensity processing operations, usually with the most disagreeable results.

In the original process for isolation of radioactive barium at Oak Ridge, use was made of a precipitation step with an ethyl ether-hydrochloric acid mixture. When the step was prolonged or repeated, or when the activity level was increased, tars and resins were produced. Subsequent tests showed that this effect was produced by about 0.14 w.-hr./g. ether-acid solution. A destructive effect was also observed with a Versene reagent, where the destructive dose was estimated at 0.04 w.hr./g. Versene. No deleterious effects were observed with acetates, which leads to the supposition that only gaseous products were formed by radiation damage.

radiation uses

The water boiler at the University of California's Los Alamos Scientific Laboratory was the first homogeneous reactor ever developed. It is used as a source of neutrons and for irradiation studies. Its fuel is uranyl nitrate enriched in uranium-235 and it operates at a power level of 35 kw. Five more reactors are being designed or built at Los Alamos.

—courtesy Los Alamos Scientific Laboratory, University of California

Two important conclusions may be drawn from contemplation of the effect of radiation on organic materials: *one* is that, without careful testing, organic reagents should be excluded from high intensity processing schemes; *the other* is that the free radicals resulting in organic materials upon irradiation can combine in ways unattainable by conventional methods. This employment of nuclear radiation to produce useful new substances will undoubtedly result in an important branch of a high-intensity chemical processing industry.

HOT-ATOM EFFECTS

Hot-atom effects are those in which the particular atom undergoing a nuclear event, such as neutron absorption, fission, etc., manages to characterize itself chemically to so profound a degree that notice may be taken of it processwise. The classical example is the well-known Szilard-Chalmers process. It must suffice here merely to mention this type of effect as one which may lead to rapid and unusual means for isolating particular isotopes in extremely high specific activity. Each such process would be highly specialized.

A negative version of a hot-atom process is observed with dismay in homogeneous reactors, the corrosion resistance of which lies in a protective oxide film. If an uranium atom can penetrate the film slightly, it will sooner or later undergo fission and literally blow off a piece of the protective film.

Unit Operations

Chemical processing of radioactive materials involves, at many points, phase separating steps or unit operations, such as filtration, resin bed separation, distillation. Although it is difficult to make general deductions from the few known high-level processes, six such operations will be discussed as to radiation effects and means of overcoming them. Attempts to estimate energy input levels, which can be successfully handled, must be regarded as subject to considerable uncertainty since each case will have its own variations on quantity, geometry, acceptable performance standard.

FILTRATION

Filtration has been avoided as much as possible in remote-control processes because means for setting up and cleaning the filter and handling the separated solid have been difficult to achieve remotely. The usual techniques of precoat, belt-discharge, and the like cannot be considered in their present form because of maintenance difficulties, lack of miniaturized models, and also because the filter aid forms a bulky disposal problem.

There is no particular reason, however, why a successful filtration technique cannot be devised for use in a high radiation-intensity process. Porous metallic filter media, such as stainless steel and platinum, have been used with good success in small-scale operations. The equipment must be arranged so that the filter can be cleaned or replaced with ease.

CENTRIFUGATION

The centrifuge has always been an attractive alternative to filtration for liquid-solid and for liquid-liquid separations. There appears to be no reason why the centrifuge cannot effect phase separation at the highest activity levels. However, the type of machine must be selected carefully. The laboratory batch centrifuge has been used in small-scale work, but in all cases described, after stopping the centrifuge the compacted precipitate became dislodged because of gas evolution before decantation could be performed.

The obvious solution is to use a continuous-discharge-type centrifuge. The precipitate can be reslurried and washed or removed as desired. Such a centrifuge has been designed for a moderate scale, high-intensity process. There are no indications that this type of centrifuge separation will be limited in any way by radiation intensity.

DISTILLATION-EVAPORATION-IGNITION

In all these operations the self-heating of the radioactive materials can be used to aid the operation. All have been accomplished by remote control at low intensity with the nearly conventional equipment. Evaporation and ignition operations with radioactive lanthanum materials at high specific activities showed less splattering losses than when evaporation and ignition operations were performed with external heat.

Waste air streams bearing radioactive particulate matter can be scrubbed with highly contaminated waste water, with transfer of radioactivity only from the air to the water. Liquid wastes may be readily concentrated many fold by distillation.

ELECTRODEPOSITION

Electrodeposition of radioactive materials will undoubtedly be limited to specialized applications.

SOLVENT EXTRACTION

Selective extraction by contacting of aqueous solutions with immiscible organic solutions is discussed elsewhere in detail. Because of the organic materials involved, these methods are far from qualifying as high radiation-intensity processes. The best organic-complexing materials can be exposed to only 0.0001 w.-hr./g.

Solvent-extraction methods are made use of for highly radioactive materials by diluting the solutions. For large-scale work this means large shielded plants, but the simple equipment of the solvent-extraction system compensates economically. There are some radioactive products which cannot be handled at high dilution, and there are cases in which the large scale will weigh against the solvent system.

ION EXCHANGE

An important contribution of the atomic program to industrial technology has been the exploitation of ion-exchange separations. These have enabled large-scale separation of pure rare earths, the isolation of new transuranium elements. In the field of high radiation-intensity processing, ion-exchange techniques appear to hold a promising position.

In the separation of radio-barium an organic cation exchange resin of the sulfonated phenolic type has been used at dosages up to .270 w.-hr. of beta energy/g. The loss in capacity of the resin was about 4%. Anion resins were shown to have less radiation stability than cation resins.

An example of the use of an inorganic exchange bed is the process for production of fission product zirconium using a silica-gel adsorption column. The column was operated successfully for sorption and elution of zirconium in a flux depositing 0.025 w./g. No ill effects were observed and this dose rate is believed to be far from the upper limit.

In addition to possible destruction of the exchange bed material, the most probable limitation which radiation intensity will place on ion-exchange columns is the formation of gas bubbles, which tend to plug the column. Various attempts are being made to overcome this limitation by such devices as upflow columns, pressurized columns, etc

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radiation uses

IRRADIATION OF LONG-CHAIN POLYMERS

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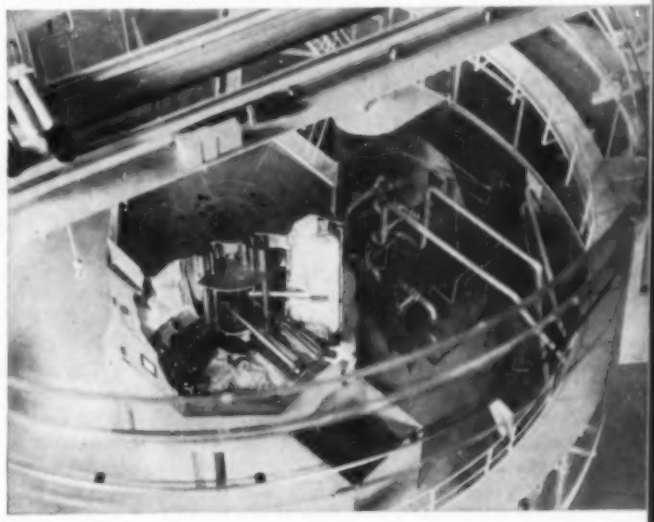
Two major effects have been observed in long-chain polymers exposed to high-energy radiation. The first is termed cross-linking and corresponds to the formation of bridges or links between molecules, such links consisting of new primary bonds. As a result a specimen is transformed from an assembly of separate linear or branched molecules held together by weak secondary forces into a three-dimensional network, each atom being linked to the others by primary bonds. The whole specimen now consists of a single gigantic molecule which cannot be melted, and whose properties depend on the density of these links. It is therefore possible to modify to any desired extent the physical properties of such materials, merely by varying the radiation dose. The formation of these crosslinks has been ascribed to the fracture of side chains, leaving an activated molecule or radical which can then attack a neighboring molecule and

form a permanent link with it. At first this results only in an increase in the average size and complexity of the molecules initially present, but further radiation forms links between parts of the same molecule and eventually leads to a network structure.

The phenomenon of cross-linking occurs only in a certain number of polymers. In others the effect of radiation is to break the main chain; if the two fragments formed can be stabilized by a rearrangement of a few atoms, a permanent break results, and the average molecular weight is reduced. By repetition of this process it is possible to reduce a high molecular-weight material which is solid at room temperature down to a very viscous liquid. The average molecular weight of the irradiated material is directly dependent on the number of breaks, i.e., on the radiation dose.

In certain polymers both processes, i.e., main-chain and side-chain fracture, occur simultaneously. It is of general interest to discover why irradiated polymers behave in these two alternative ways. As a general rule polymers with two side chains tend to suffer main-chain fracture and those with one side chain or none cross-link. In this connection hydrogen (which can readily diffuse away) is not considered as a side chain. However, there are certain exceptions to this general statement, and these are now being studied.

In the study of radiation-induced polymerization reactions, the effect of radiation is to produce radicals which then react in a manner typical of the conventional chemically produced processes. The final product is identical with one which would have resulted under the same conditions had these radicals been produced in some other manner. In cross-linking or main-chain fracture this similarity does not hold, and the effects produced by radiation do not necessarily follow the pattern to be expected from their chemical structure, for example, the process of main-chain fracture and depolymerization, induced thermally, is quite different from that which results from radiation. Chemical bonds with low-binding energies often are more resistant to radiation changes than stronger chemical bonds. It is therefore not possible to predict purely on chemical grounds the course of such reactions, and it is necessary to study anew the chemical stability of molecules when reactions are initiated by radiation. There is a growing body of evidence to show that such reactions occur in at least two separate stages. In the first of these, excited or ionized molecules or radicals are formed at random, simultaneously with the passage of the ionizing radiation through the specimen. A relatively long period of time may elapse then during which the energy captured can travel freely throughout the molecule (possibly in the form of an unpaired electron) during which time the molecule may suffer an atomic rearrangement. Only after this will the final reaction take place.



Shown is a close-up view of a model of Argonne National Laboratory's research reactor (CP-5), which is a heavy-water, moderated, and cooled reactor. The cutaway section reveals the uranium-bearing fuel assemblies and the experimental facilities. The reactor was constructed in 1953.

—courtesy Argonne National Laboratory

This need to consider a radiation-induced reaction as falling into separate stages is demonstrated by the possibility of modifying such reactions (even in the solid phase) by the addition of small amounts of inhibitors which cannot directly absorb an appreciable proportion of the incident energy, yet which can affect profoundly the nature of the final product. It can only be assumed that these inhibitors play their part in the subsequent processes, by collecting this energy from neighboring molecules, which are thereby protected from radiation damage.

An experiment which demonstrates this multistage process concerns the irradiation of polyisobutylene at various temperatures. This polymer suffers main-chain fracture and reduction in molecular weight as a result of exposure to high-energy radiation. The energy absorbed per main-chain fracture is about 20 e.v. at room temperature, an energy far greater than is required to break a C—C bond. The energy per fractured bond varies with the temperature of the specimen during irradiation—a surprising observation since it would appear unlikely that a temperature change corresponding to only a few thousandths of an electron volt could seriously affect a reaction requiring about 20 e.v. It must be concluded that the final reaction leading to decomposition must take place after an interval of time sufficient for the molecule to have returned to thermal equilibrium with its surroundings.

It is possible to obtain valuable information from the irradiation of solutions of long-chain polymers, which can be gelled at concentrations as low as 0.5%. The radiation dose needed to induce gel formation is found to decrease with decreasing concentrations, so that polymer molecules further apart in the solvent are apparently more readily linked together.

The explanation of this apparent anomaly depends on the possibility of both direct and indirect effects, often studied in radiobiology. In the former case, radiation affects a polymer molecule directly; in the latter case it operates on a solvent molecule which is thereby rendered active in some way. This active solvent molecule can subsequently react with a polymer molecule, rendering it in its turn active. The direct effect is of course independent of concentration, whereas the indirect effect will be more important in dilute solutions, when there will be fewer polymer molecules available to share the activated solvent molecules. In either case the polymer molecules activated either directly or through the intermediary of the solvent molecule can attach themselves to neighboring polymer molecules to form a gel structure as in the solid. In dilute solutions this process does not take place as the polymer molecules are too far apart to link and form a network; presumably this activity is dissipated in other ways, e.g., by internal linking.

The study of such polymer-solvent systems offers a useful method of comparing the mechanism of direct and indirect action, and a means for exploring the effect of polymer separation on the cross-linking process. It is also a useful tool in measuring the susceptibility of different chemical groupings to attack and may provide insight into the nature of the interaction between active solvent molecules and the polymer. The action of certain additives which in dilute concentration inhibit or reduce the effect of radiation has also

been investigated. In this manner it is possible to decide whether the inhibitory action applies only to the indirect effect, or the direct effect, or whether it interferes with the subsequent process of cross-linking and gel formation.

From the applied aspect, the modification of polymeric materials as an industrial process will need considerable quantities of high-energy radiation at an economic cost. Such radiation can be obtained from suitably designed atomic piles, fission products, radioactive isotopes, or from electrical accelerator equipment. In assessing the economics of atomic power, account must be taken of the high-energy radiation which can be simultaneously produced, and which may offer a valuable financial contribution to the cost of operating atomic piles. Uses to which such radiation can be put are already manifold, but the price at which it is offered must be competitive with that of the electrical accelerators. From the economics of existing and projected accelerators it is possible to deduce an upper limit for the cost at which high-energy radiation obtained from atomic energy sources can be sold.

radiation uses

RADIOLYTIC OXIDATION OF ORGANIC COMPOUNDS

Nathalie Bach

U.N.–A/Conf. 8/P/683

Production of useful compounds by chemical reactions taking place under the action of radiations is one of the important branches of atomic energy applications. In this respect the action of radiations on organic compounds is a promising and interesting field.

The specificity of ionizing radiations' action is manifested in the formation in an irradiated system of a large number of free radicals with excess of kinetic energy and of molecules excited to various levels at all temperatures, down to the very lowest. Charged particles (ions) may also play a certain part in the reactions, but this part is usually much less important due to the shortness of their lives.

Molecular oxygen is an efficient acceptor for most organic radicals. Reactions involving the formation of peroxide radicals possess the advantage that their final products are easily identified and can readily be quantitatively determined. A study of radiation chemical processes in organic systems in the presence of molecular oxygen allows one to ascertain the role of the primary radicals in the basic mechanism of these processes, and at the same time opens new ways of producing oxidation products of practical interest from chemically inert substances.

Molecular oxygen plays an important part in the radiolytic oxidation of organic compounds not only as such, but in aqueous solution as well. In the latter more complicated case, the efficiency of the radiation energy absorbed may be substantially increased by the presence of inorganic components, particularly by ions of variable valency.

The chemical individuality of the end products of radiation chemical processes depends primarily on the nature of the active particles formed under the action of the radiation. These primary uncharged particles may be divided into three groups as follows:

1. free radicals, resulting from the ionization of molecules and showing tendency to combine into the initial molecule at the moment of their formation.

2. free radicals, forming as a result of the dissociation of an excited molecule and showing a marked tendency to recombine into the initial molecule, particularly in the liquid state; radicals of this type play a substantial part in radiation chemical processes only in the presence of acceptors, which bind one of them, freeing the other for subsequent reactions.

3. excited molecules, which decompose into molecular products or react with other molecules without dissociating into radicals.

Free radicals may react with unexcited molecules of the substratum initiating chains or may enter into nonchain reactions with each other. The nonchain mechanism is also characteristic of reactions between excited molecules which do not dissociate into radicals.

Experimental data show that the predomination of reactions of one type or another in chemical systems subjected to the action of radiation, depends on the structure and properties of the irradiated compounds. The general regularities governing this relationship are one of the important problems of radiation chemistry.

Some information on the primary radicals of the first type can be had from mass-spectrometric data.

In the majority of cases these data are obtained with electron energies not exceeding 100 e.v., which is much lower than the energy of the ionizing particles dealt with in radiation chemistry. It should, however, be taken into account that a considerable part of the ionization acts occurring under the action of high-energy ionizing particles are due to secondary electrons with energies not more than several hundred volts. The influence of the electron energy on mass-spectre has been studied within a range of 20 to 1,000 e.v. As the energy of the electrons increases up to 1,000 e.v., the amount of low-mass fragmentary ions, the contribution of which to the spectrum is relatively small, decreases somewhat, thus causing a corresponding increase in the importance of the main ions. The change in the relative quota of the latter does not exceed a few per cent. It is thus permissible to use mass-spectrometric data in concluding on the nature of the primary ions formed in radiation chemical processes.

With their charge neutralized the radical ions become free radicals, which may retain the structure of the initial ion if the conditions for energy dissipation are favorable. Mass-spectrometric data may be used also to conclude as to the structure of the free radicals formed simultaneously with ions when molecules dissociate under impact.

Data may often be obtained from studies of photochemical processes on possible reactions involving molecules excited to energy levels too low for ionization with consequent dissociation into radicals.

The radiation chemical processes considered here include both reactions involving primary radicals and reactions with the participation of excited molecules.

A. Action of Irradiation on Individual Organic Compounds in Presence of Molecular Oxygen

Almost no data appear in the literature on irradiation action on individual organic compounds in the presence of oxygen. The only system studied in

Table 1.—Irradiation of Acetic Acid

Reaction products from irradiation of acetic acid	Yield, molecules/100 e.v. in the presence of O_2	Yield, molecules/100 e.v. without O_2
Hydrogen peroxide and acetyl hydroperoxide	0.36	0
R_1OOR_2 (acetyl peroxide)	0.78	0
ROOH (methyl hydroperoxide)	1.1	0
Formaldehyde	1.1	0
Acetone	0.45	0.45
Total gases liberated	2.4	5.4
Carbon dioxide	2.4	2.4

some detail is the system chloroform-oxygen. In studies reported the objects selected were hydrocarbons of various structure: *n*-heptane, isooctane (2,2,4 trimethylpentane), cyclohexane, toluene, benzene, acetic acid, and ethyl and benzyl alcohols. Discussion of these has been eliminated from this paper.

In general it may be stated that under the action of ionizing radiations both peroxides and end products of oxidation including carbonyl compounds, acids, in the case of benzene-phenol, etc., are formed in all the systems. The products are for the most part similar to those produced in photochemical reactions and auto-oxidation, but the differences in the relative yields and in some cases, in the nature of the compounds formed are specific for the action of ionizing radiations.

EXAMPLE OF FINDINGS

Acetic acid is stable towards radiolytic oxidation. Table 1 shows the initial yields of the products in the presence of oxygen compared to those obtained without oxygen.

It is a characteristic feature that if the acetic acid is saturated with oxygen, no methane, hydrogen, or carbon monoxide forms during the initial phase of irradiation, though these gases constitute more than half the total gases liberated when oxygen is absent. This points to the conclusion that the radicals which lead to their formation react efficiently with oxygen to form peroxide radicals. A parallel analysis of the liquid and gaseous phases shows that in the beginning, when the peroxides are accumulating, the formation of carbon dioxide is balanced by the absorption of oxygen, so that no liberation of gas is observed. At a definite dose the peroxides begin to decompose, liberating CH_4 and additional carbon dioxide and upon further irradiation a steady-state concentration of peroxide is established. This explains the induction periods in the evolution of gases observed on irradiation of different organic systems in the presence of oxygen.

Table 2.

	Molecules/100 e.v.			
	saturated with O_2			without O_2
Dose rate e.v./cc./sec.	2×10^{16}	1×10^{17}	2.9×10^{17}	2.9×10^{17}
Products from	irradiated ethanol			
Peroxides ..	6.0	3.6	2.3	0
Aldehyde ..	7.5	4.2	3.6	1.0
Acid	3.6	4.8	7.2	0
Water	4.8	...	7.2	2.1
H_2	...	12	...	6.0
CO	...	1.8	...	0.3
CH_4	...	0.9	...	0.2
CO_2	...	0.1	...	0.03
O_2 absorbed...		11.3	...	0

The picture presented by alcohols when subjected to oxidizing radiolysis is substantially different from that of hydrocarbons and acetic acid. Already in the case of ethyl alcohol the total amount of products formed is considerably higher. Data on the yields obtained under various conditions are given in Table 2. If the concentration of oxygen is kept constant, the yields remain constant throughout the range of doses studied up to $\sim 1.5 \times 10^{21}$ e.v./cc.

As can be seen from Table 2, irradiation of oxygen-free alcohol also leads to the formation of a considerable amount of radiolysis products, including aldehydes, water, and hydrogen. In the presence of oxygen the yields of all these products increase and new products—acids and peroxides—are formed.

The considerable increase in the amount of hydrogen liberated is particularly striking.

In this case the total yield of products can no longer be secured by the free radicals because of ionization, and a participation of excited molecules in the reactions cannot be discarded.

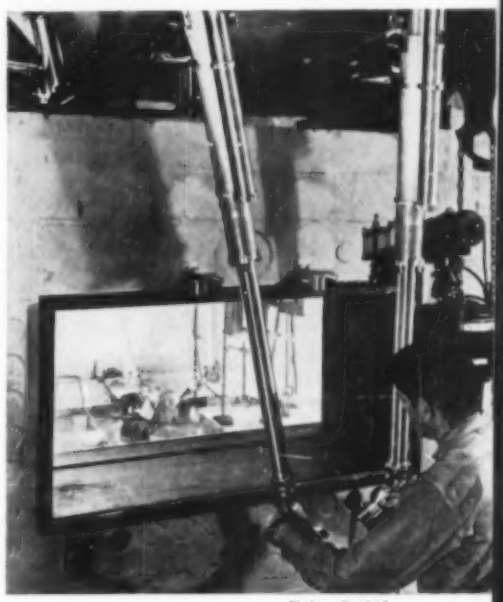
The examples cited show that in reactions of radiolytic oxidation, even more than in pure radiolysis, the individual properties of the irradiated molecules depending on their structure and on the presence of definite functional groups play a decisive part in determining the trend of the processes and the yields.

B. Action of Irradiation on High Polymers in Presence of Oxygen

Changes which take place in the mechanical properties of high polymers under the action of irradiation were explained in recent literature as being due to ruptures of the C—H bonds and to a subsequent recombination of the free radicals to form new relocating bonds between the molecules or to rupture of the C—C bonds (destruction). Changes observed when polyethylene is irradiated in the presence of air are connected with oxidation reactions which take place at the surface.

It is of substantial interest to establish the functional nature of these products since it is necessary to ascertain the character of the new bonds that form in order to determine their role in the changes that take place in the physical properties of the polymer.

The red and ultraviolet spectra of thin films of polyethylene have been subjected to radiations of fast electrons under vacuum and in air. Definite changes are observed in the spectra, which increase regularly with the dose of energy absorbed. Analysis of the absorption bands has shown that besides the appearance of double bonds and branched chains and the transition from the crystalline to the amorphous state, irradiation in the presence of air leads to the formation of carbonyl, carboxyl, and ether groups. The latter account for the increase in the rigidity of the polymer by cross-linking it with "oxygen bridges." The main mechanism of the formation of these oxidation products is the same as in the case of low-molecular hydrocarbons, i.e., it is based on the addition of molecular oxygen to the free radicals formed under the action of the irradiation and the subsequent transformations of the peroxide radicals. The particular course of these reactions in polymers is connected with the limited mobility of the macromolecules.



Union Carbide

After a period in the reactor, the now-radioactive substances are studied by research physicists at Oak Ridge National Laboratory who work behind protective windows of the "hot" cells and perform operations within them by means of remote control-manipulators.

radiation uses

COLD STERILIZATION OF FOODS

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U.N.–A/Conf. 8/P/172

It has been possible to demonstrate the ability of radiations to destroy all types of microorganisms in every conceivable type of package, so long as the dimensions of the package do not exceed the limitations imposed by the particular type and energy level of radiations used. The species of organism is the prime factor in determining the magnitude of the sterilizing dose. Environmental factors are important in the survival ratios of microorganisms exposed to ionizing radiations.

Microbiological factors involved in radiation sterilization indicate the hazards in applying any one set formula for the use of ionizing radiations to destroy all species of microorganisms that may contaminate a food. They also demonstrate the necessity of time-consuming, tedious research under the particular experimental conditions to be encountered in processing with each particular contaminating species.

The examples just cited relate to experiments conducted with *B. subtilis* spores and with *E. coli*. Data obtained for *E. coli* might well have been predicted theoretically, from the qualitative standpoint at least. The results obtained with *B. subtilis* spores, on the other hand, were quite contrary to accepted theory and could not have been predicted.

Research on the microbiological effects of radiations may be considered to be advanced further than research on some other aspects. Studies are in progress at present on the complementary effects of heat and radiation, which may greatly reduce the radiation requirements for particular species of organisms.

Studies are underway on applying to radiation processing certain fundamental nutritional and environmental factors known to speed germination of spores. These studies may well lead to other means of obtaining increasing economy in the doses of radiation used.

The chemical effects of ionizing radiations on foods have not been overlooked; it has, for example, been observed that radiations affect isolated components of a mixed solution of nutrients to a greater or less degree, dependent on the particular component, its concentration in solution, its purity, and the radiation dose. Each particular nutrient might be classified as to its relative radiosensitivity (Table 1).

The types of effects that might be observed include (where applicable) decarboxylation, deamination, cleavage of aromatic rings, oxidation of sulfhydryl groups, and many others. With niacin and para-aminobenzoic acid, radioactive tracers have been used to study the nature of the effect.

These indirect effects of radiations, which occur as the result of the absorption of large amounts of energy in the radiation sterilization process, exhibit not only the phenomena associated with dilution, rate of reaction, and temperature dependence to be expected according to the indirect action theory but also the phenomenon of protection in mixed systems (see Table 2). The comparison given in Table 3, which shows that vitamins in pure solutions are relatively more radiosensitive than vitamins in foods, illustrates the protective nature of the complex food material. A further illustration of this protective action is given by the comparison in Table 4.

These data demonstrate that nutrients may be affected by ionizing radiations, but that the effect is dependent on the phenomena mentioned above.

Because enzymes are, for the most part, protein molecules, they might well be expected to react to ionizing radiations as do proteins or other solutes. They exhibit the same phenomena associated with dilution, temperature, and protection that are observed with proteins, amino acids, and other molecules of biological importance. As a consequence, enzymes are not completely inactivated by sterilizing doses of ionizing radiation. In fact, under a number of conditions enzymes are neither completely inactivated nor even inactivated to a desirable extent by doses of ionizing radiations ten to twenty times the magnitude of those doses required for sterilization.

Table 1.—Relative Radiosensitivities of Amino Acids in Aqueous Solutions

Amino acid	Specific inactivation dose (D_o/C) (r.e.p./g./ml.)
dl-phenylalanine	1.18×10^5
l-histidine	1.25×10^5
l-cystine	2.40×10^5
l-tyrosine	2.60×10^5
l-leucine	3.60×10^5
dl-tryptophan	10.00×10^5

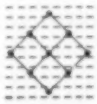
Table 2.—Effect of High-voltage X-Rays on Solutions of U.S.P. Niacin, U.S.P. Ascorbic Acid, and on Mixtures of the Two

(dose = 125,000 r.)

Solution	Concentration before irradiation		Retention after irradiation	
	Niacin (γ/ml.)	Ascorbic acid (γ/ml.)	Niacin %	Ascorbic acid %
Niacin	50	...	86.0	....
Ascorbic acid	..	500	....	66.6
Niacin-ascorbic acid mixture	50	500	44.0	83.6

Table 3.—Specific Inactivation Doses of Ascorbic Acid and Riboflavin Irradiated *per se* and in Evaporated Milk

Irradiated medium	Specific inactivation dose, D_o/C(r./g./ml.)
Ascorbic acid—pure solution	$1.19 \times 10^5 - 3.6 \times 10^5$
Ascorbic acid—evaporated milk	2.4×10^{10}
Riboflavin—pure solution	$2.6 \times 10^5 - 5.2 \times 10^5$
Riboflavin—evaporated milk	3.7×10^{11}



radiation uses

Because the spoilage of certain foods occurs partly through enzymatic action, it is usually necessary that these biological catalysts be inactivated. In most thermal processes the amount of heat used for sterilization is sufficient to inactivate the enzymes, but in radiation sterilization ("cold sterilization") some other means for enzyme inactivation could be used to advantage. The possibility of applying high-frequency electronic heating is intriguing. Such application may well prove to be feasible, as it is a rapid, efficient, and satisfactory method for this purpose. The properly controlled use of microwave heating results in even heating throughout the mass of food and thereby avoids overheating of the exterior surface while producing only the minimal quantity of heat needed for enzyme inactivation in the interior of the food mass.

Problems in Radiation Sterilization

Some indirect effects of ionizing energy have given rise to the greatest problems existing today in radiation sterilization, namely changes in color, texture, and flavor of irradiated foods. The fundamental studies mentioned previously here have suggested several technological means of obviating these undesirable side-reactions. These include (a) irradiation of food in the frozen state, (b) irradiation in inert atmospheres, and (c) addition of free-radical acceptors.

In addition to the chemical changes occurring in the protein components of irradiated foods, modifications in the structure of carbohydrates are observed. The changes in lipoidal material have been studied by several investigators, with interesting results. Data obtained indicate the complex interaction that takes place among the many components of which foods are comprised.

The basic effect of ionizing radiations responsible for destruction of nutrients is probably also the simultaneous cause of changes in flavor, and any means of reducing the one effect may be a means of reducing the other.

These same indirect effects have given rise also to speculation on whether any compound of a toxic nature might be produced by these radiations. Evidence has been lacking that ionizing radiations produce compounds of a toxic nature in foods. Destruction of nutrients has been noted, but this occurs even with conventional heat processing and is not unexpected.

A problem closely related to that of wholesomeness or toxicity of irradiated foods is that of a possibly induced radioactivity in irradiated foods.

Recent research on the sterilization of milk has indicated that many of the undesirable changes taking place in irradiated foods occur almost immediately. Therefore, any efforts to avoid these undesirable changes must be made during or before the irradiation process. This research has resulted in a technique for obtaining an acceptable milk product treated by ionizing radiations in doses up to 10^6 r.e.p. (roentgen-equivalent-physical).

Great strides have been made in the design, fabrication, and utilization of radiation sources. Multikilowatt sources of fast electrons are now available at increasing energy levels, and kilocurie isotopic sources have been developed. Reactors for this purpose, as well as megacurie isotopic sources, are now in fabrication. All this has been partly instrumental in enabling increases in the research effort in this field.

There are problems relating to the use of these sources of radiation; for example, there is a continually occurring economic loss with an isotopic source through its nuclear disintegration and the necessity for replenishment.

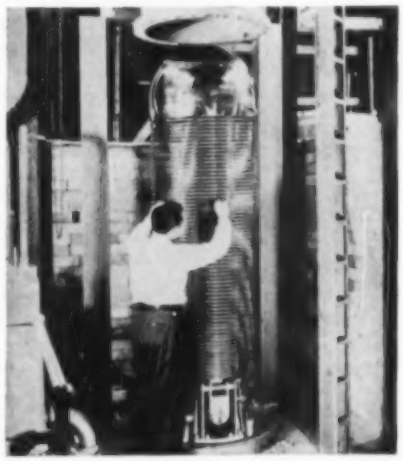
It would be most efficient, in theory at least, if this nuclear energy could at all times be absorbed by foods requiring sterilization. Since many food plants are widely dispersed in location and their operation is often highly seasonal in nature, this is not possible. Plants that operate 24 hr./day throughout the year are in the minority, and many now work only one 8-hr. shift/day, five days a week.

The use of particle accelerators also presents problems; these relate to the amount of development necessary to produce machines of high output reliably delivered over extended periods of time during the harvest season.

Packages also present certain problems, because during storage a food material can be of no better quality than the functional properties of the package in which it is contained. Some of the plastic containers require study to determine the effect of the radiations on them; certain plastics are known to degrade on irradiation whereas others cross-link. The question arises whether these changes affect the functional properties of the containers. With certain plastics, no such effects have been observed.

Table 4.—Effect of Cathode Rays (dose 5,700,000 r.) on Amino Acids in Haddock Fillets

Amino acid	change in amino acid: loss	gain
	%	%
Phenylalanine	6.10	0.00
Tryptophan	6.92	0.00
Methionine	4.68	0.00
Cystine	0.00	0.00
Valine	0.00	6.36
Leucine	0.00	2.74
Histidine	0.00	8.11
Arginine	0.00	4.12
Lysine	4.23	0.00
Threonine	5.95	0.00



Voltage-generating column of Gulf Oil Corporation's 3-million-volt Van de Graaff particle accelerator, the most powerful and versatile radiation source of its type in private industry.

Because, in general, the penetrability of radiations into foods is related to the product of thickness and density of the packaging material, it is obvious that a metal container as thin and of as low a density as possible is desirable. Metal containers need not be so rigid as those used for thermal processing, because they need not withstand the heavy pressures of retorting. Hence savings may result.

Applications of Radiation Sterilization

Certain limited applications appear today to be possible. For example, it seems possible that pharmaceuticals such as antibiotics, and others such as steroidal compounds may be sterilized by ionizing radiations. Because pharmaceuticals are relatively simple compounds and changes produced by irradiation are less in degree as compared with foods, they lend themselves more readily to tests for chemical changes induced by ionizing radiations. These and other facts cause us to predict that the first industrial application of radiation sterilization may be with pharmaceuticals.

Other interesting and important applications of ionizing radiations are the sterilization of segments of human aortae for subsequent surgical transplant and surgical sutures.

Ionizing radiations may also be used for the sterilization of the surface of certain foods, to increase shelf life. Fivefold increase in shelf life of meats

irradiated with low doses of gamma radiation (less than 100,000 r.e.p.) has been reported.

By the application of free-radical acceptors, the irradiation dose may be increased to 800,000 r.e.p. without detectable side reactions, and the shelf life of irradiated comminuted meats at 36° to 40° F. may be increased from five to seven days for the control sample to three months for the irradiated product. Similar promising results in preservation have been obtained with other meat products.

Insects can be destroyed by relatively low doses of ionizing radiations (fewer than 50,000 r.e.p.). This may be a means of saving millions of dollars now lost annually because of destruction of cereals by insects. A relatively low dose of radiation is required, indicating low cost. Ionizing radiations successfully inhibit sprouting of potatoes at low doses (approximately 20,000 r.), increasing storage life by many months. Whether this method can compete with chemical means of inhibition is as yet unknown.

If research is continued at present levels toward solution of the problems just cited, it would seem conservative to predict the initiation of commercial processes for irradiation sterilization of some pharmaceuticals, foods, tissues, and packaging materials in the present decade.

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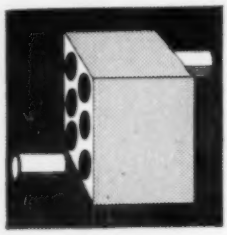
reactor fuels



REACTOR FUELS

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Nuclear reactors employed for research and for power production have used at least nine different fuel elements or systems. As many more systems have received detailed study and evaluation and the number under study is still increasing. This paper discusses the following: (1) distinct types of fuel elements, their applications, the requirements on them, and their limitations, and (2) essential materials and metallurgical methods used in the manufacture and processing of elements.

1. Fuel Types, Applications, Limitations

Solid and fluid systems form two distinct classes, each of which may be subdivided into several families. The central problem in the technology of power reactor fuel systems is to maximize specific power and life, subject to a large number of conditions arising from the type reactor, use for the power, and the methods of reprocessing.

A. SOLID FUELS

Limitations

The anatomy of a solid fuel element is illustrated in Figure 1. The important phenomena which, in turn, establish the conditions prevailing in the element are as follows:

(1) The kinetic energy of the fission recoils is dissipated to the crystal lattice, producing effects generally called radiation damage in the manner described by several authors.

(2) The fission product atoms either take up positions close to the end of their recoil range in the material or diffuse to the most stable configuration depending on the temperature and the energy of activation for diffusion in the surroundings. Since the atomic volume of the fission product atoms is greater than that of the uranium atom, a corresponding increase in the system volume must be expected at the very minimum. If the temperature is high enough to permit movement of the inert gas fission products, nucleation and growth of gas pockets must be expected at some amount of burn-up.

(3) All except a small fraction of the fission energy appears as heat in the bulk material and flows to the lower temperature coolant.

(4) The steady-state temperatures and gradients set up determine: (a) stresses and strains, (b) reactions between jacket and coolant, (c) interdiffusion between bulk material and coating, (d) diffusion of fission products, and (e) generally the set of properties of the given systems.

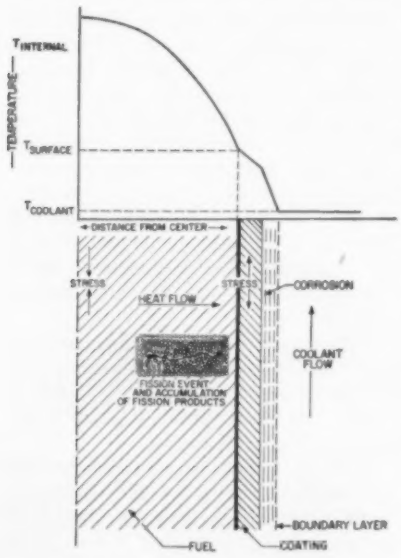


Fig. 1. Schematic diagram of fuel element heat flow.

Metallic Uranium-Base Elements

Uranium cylinders protected by aluminum cans produced the first significant amounts of nuclear heat in November, 1943, in the air-cooled graphite-moderated research reactor at the X-10 site at Oak Ridge, Tennessee. These elements, called unbonded aluminum canned slugs, may be made in any convenient size.

Long uranium rods clad in aluminum tubes fitted by drawing of the cladding onto the uranium were used in the second reactor to produce a reasonably large neutron flux. This reactor was the heavy water-moderated and -cooled CP-3 set in operation in June, 1944, at Argonne. A cross section is pictured in Figure 2a.

An improved version of the long element, consisting of *short slugs closely spaced in a finned aluminum tube* filled with slightly pressurized helium to provide for leak detection, is used in the air-cooled graphite-moderated research reactor at the Brookhaven National Laboratory (BNL).

Bonded uranium cylinders enclosed in aluminum are used in the ORNL graphite reactor at the present time. The protective aluminum jackets are brazed to the uranium by means of an aluminum-silicon eutectic alloy. Such elements are called bonded-aluminum canned slugs. A cross section is shown in Figure 2b.

The family of aluminum-clad uranium elements may be used at surface temperatures at which aluminum gives suitable service. In air this is slightly in excess of 300° C. In water conditions of corrosion limit the temperature to near 100° C. unless precautions are taken. Recently it has been found how to achieve

tolerable corrosion rates at temperatures approaching 300° C. If the temperature of a clean uranium-aluminum interface exceeds 300° C., interdiffusion becomes rapid compared to the life of unbonded fuel elements. In the case of the Oak Ridge unbonded aluminum canned slugs, this interaction occurred at random sites, producing bumps which in some cases leaked air permitting destruction of the slug. The aluminum-silicon bonding procedure served to provide a uniform interaction layer which does not thicken significantly with time in the neighborhood of 300° C. Moreover, any leak in the aluminum can provides corroding conditions only in a very localized spot, in contrast to the case of a leak in an unbonded element. The solution of the problem of the aluminum-uranium interaction found at Brookhaven was the interposition of an anodic coating on the inside of the aluminum tube. As mentioned above, detection of leaks through the jacket is assured by a helium pressure monitoring system connected to each element.

At a given velocity of cooling air, the flux of heat depends on surface temperatures of the element. Reasonable air velocities and the accompanying practical pumping power for research reactors, together with the limiting surface temperature, tend to limit heat flux, depending of course on the expense found acceptable for the cooling system. Thus the air-cooled reactor provides an example of limitation of performance by surface limitations on temperatures.

Liquid-metal-bonded uranium cylinders in steel or other material of reasonable high-temperature strength have been developed and used in a sodium-cooled reactor. The experimental fast-breeder reactor built and operated at the National Reactor Testing Station, Arco, Idaho, by the Argonne National Laboratory employed 1-cm. diam. highly enriched uranium slugs in stainless steel tubes filled with a sodium-potassium alloy usually called NaK. The sodium-cooled graphite-moderated experimental power reactor under construction near Los Angeles, California, uses ¾-in. slugs (1.9 cm.) of slightly enriched uranium similarly contained. A schematic cross section of such an element is given in Figure 2c.

The sodium or the sodium potassium alloy used to cool the above-mentioned elements can provide heat transfer at least at the rate of 500 w./sq.cm. (1.59×10^6 B.t.u./(sq.ft.)(hr.)) and with corrosion rates less than 0.0001 in. (0.00025 cm.)/yr. at 500° C. Therefore, limitations arise from internal properties of the element.

The chief use of these elements is for power production which favors coolant temperatures near 500° C. to obtain high steam-plant efficiencies. If the temperature of the alpha-beta transformation, 660° C., is taken as a limiting central temperature because of the severe distortion which can occur if uranium is repeatedly heated and cooled through the transformation, then another example of limitation is provided. The use of uranium alloys may remove this limit.

Top plug of Materials Testing Reactor at AEC's National Reactor Testing Station being removed, showing control rod lifting shafts.
—courtesy Idaho Operations Office

With steel jackets the limiting surface temperature is lower than the iron-uranium eutectic temperature, 725° C. since near this temperature rapid interaction of jacket with slug would occur at points of contract. Use of zirconium as a jacket or as a barrier layer will obviate this difficulty.

Bonded uranium rods enclosed in zirconium would appear to offer an attractive family of elements for reactor use. The bond between these metals is strong and interdiffusion is acceptably low below 800° C. Such elements have been studied experimentally, their use contemplated in power systems, but no reactor has been built using them.

Use of uranium-base elements in commercial power reactor will require as long life as can be practically obtained in order to reduce reprocessing costs. In thermal neutron power systems neutron reactivity changes limit burn-up to between 1 and 2%. In the case of breeder reactors much higher burn-up is permitted by this consideration. *The goal of the materials technologist is therefore set to achieve fuel elements stable to 2% burn-up as a minimum and more if possible.* It should also be clear that to increase specific power as much as possible, the smallest diameters that can be economically made and handled will be used.

Dispersions of Fissionable Materials in Well-Behaved Metallic Matrices

Aluminum-uranium alloys and the fabrication of fuel elements from them were developed expressly for use in a high-flux reactor for testing reactor materials (MTR). Aluminum fuel elements containing slightly less than 2 atom % U^{235} as highly enriched uranium, cooled and moderated with water, were proposed. Aluminum-uranium alloys of this composition after working and recrystallizing have a structure in which a dispersed phase, dominantly UAl_4, is in equilibrium with an aluminum phase containing a small amount of dissolved uranium.

A schematic cross section of an MTR element as used, is shown in Figure 3. Besides serving effectively in the MTR, this type element is being used in the several swimming-pool research reactors now coming into use. It is also being considered for commercial power reactors by Yankee Atomic Electric. The performance of such elements is limited by the permissible heat flux to the cooling water. Their life is beyond that permitted by reactivity changes for a

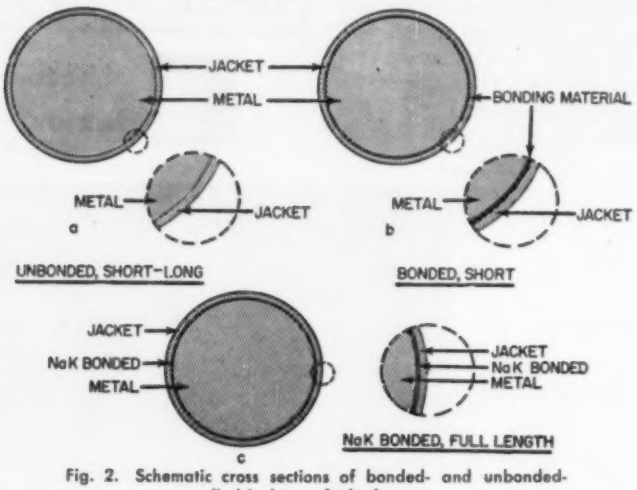


Fig. 2. Schematic cross sections of bonded- and unbonded-cylindrical-type fuel elements.

reactor and may very well be equivalent to complete burn-up of the fissionable material. Environmental conditions permitted will be those for aluminum.

The principle of the aluminum-uranium elements may quite obviously be extended to a variety of systems in which uranium or a uranium compound is dispersed in a solid matrix, the latter chosen for its desired properties which include structural service, corrosion resistance, formability, and neutron absorption cross section.

Aluminum-UO_2 dispersions are used in the pool-type research reactor set up at Geneva, Switzerland. Other inert uranium compounds, also may be dispersed in aluminum. Performance comparable to the aluminum-uranium elements may be expected.

Austenitic steel-UO_2 dispersions have been developed similarly for small water-cooled and moderated-power plants. Again performance limits are probably beyond those required by practicable reactor systems. In a high-power, high-temperature system, thermal fatigue probably places a limit on the number of times a reactor may be started and stopped. At 400° C. stainless steel will fail after a few hundred cycles at bending or thermal stresses corresponding to a heat flux of 300 w./sq.cm. through a thickness of 0.01 in. (0.025 cm.).

Thorium-uranium cylinders contained in NaK or Na filled steel tubes may serve in power reactors such as the sodium-cooled graphite-moderated reactor. Details of the optimum degree and method of dispersion of the approximately 4% U^{235} required are not solved but estimated performance of such elements is good. Central temperatures at least as high as 1,400° C. (the α-β transition temperature) should be permitted if the cooling sodium is at 500° C. and the rod diam. is 0.75 in. (1.90 cm.). Life corresponding to the burn-up permissible in the aluminum-uranium system at corresponding temperatures relative to the melting points of the two metals, should be obtainable.

Zirconium-uranium alloys clad with zirconium have been studied in some detail and have suitable properties. Here uranium may be put in solution at elevated temperatures and precipitated upon cooling in standard metallurgical fashion. Excellent specific power and life may be obtained. However, the cost of the zirconium in such elements weighs against their use in power reactors.

Plutonium

Plutonium cylinders in steel cans served in a fast reactor cooled with mercury operated for research purposes. No information exists on such elements or sources of power except that derived from the physical properties of plutonium; low thermal conductivity and transition temperatures make this element undesirable for such purposes. It is likely, however, that plutonium-uranium alloys will be used in fast-breeder power reactors. Here the metallurgical structure will be governed largely by the uranium and hence may be considered as related to that family of elements.

Ceramic Systems

BeO-UO_2 systems have been studied extensively. A high-temperature, helium-cooled, BeO-moderated power reactor was the objective. Radiation stability was established for cylindrical shapes. Volatilization of BeO was observed during exposure to a low partial pressure of water vapor at temperatures of 1,000° C., thus prescribing requirements on the dryness of any cooling gas. At operating temperatures the performance of such elements is probably limited by the heat flux to the gas coolant. However, on shutdown, thermal stresses and brittle behavior will limit either the life or the permissible thermal strain at operating temperatures.

This reactor scheme was abandoned largely because of the expense associated with a high-pressure, helium-cooling system and the fabrication of complicated bodies of BeO. However, these elements remain an attractive possibility.

Graphite elements have been developed in which the UO_2 or UC_2 is dispersed in graphite by (1) impregnation of the normally porous artificial graphite or (2) by mixing and graphitizing. One of these was for a low-power research reactor for which operating hazards were minimized. Although satisfactory under conditions customarily employed for graphite, these elements have not been used in any reactor.

Thoria and urania bodies have been developed. Since thoria is nearly as dense as thorium metal, its use as the fertile material in a reactor for conversion or breeding and power is indicated. Performance and life have not been investigated.

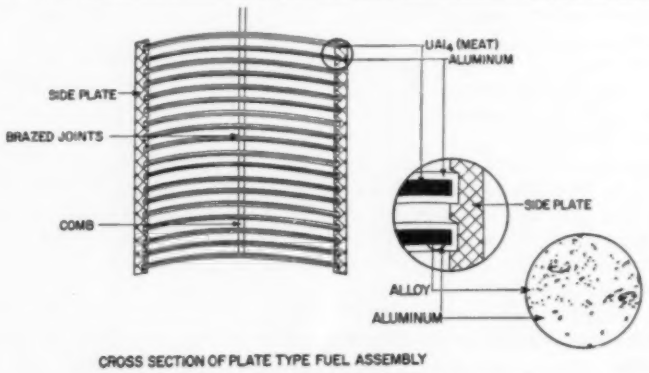


Fig. 3. Schematic cross section of MTR fuel element.

Turbo-Topics

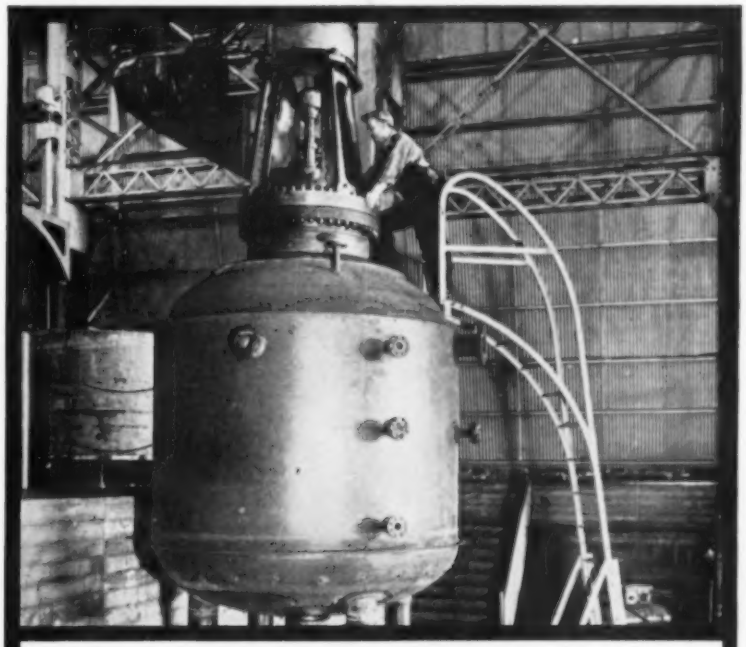
TURBO-MIXER GENERAL AMERICAN TRADE MARK

TURBO-MIXER, a division of

GENERAL AMERICAN TRANSPORTATION CORPORATION

*FROM ASPHALT FILLING TO XYLENE EXTRACTION**

production flows faster with TURBO on the job



Turbo Contactor For Butane Isomerization: *furnished to C. F. Braun & Co., Engineers and Constructors as part of a plant built by them in 1942 for a West Coast petroleum processor.*

For over 25 years, Turbo has supplied leading oil companies with precision-built mixers for petroleum processing. In many plants, the original Turbos are still in operation—after more than 20 years of continuous 24-hour maintenance-free service. This outstanding service record is a testimonial to the rugged design built into each and every Turbo. If you have a process problem, call on Turbo. A Turbo engineer is always available to work with your engineers on request.

***How the petroleum industry uses Turbo-Mixers**—Asphalt filling, asphalt oxidation, asphalt cut back blending, spent doctor oxidizing, doctor treating, drilling mud mixing, lube blending, solvent extraction and many others.

Send for technical bulletins describing the use of Turbo-Mixers in the petroleum processing field.

SALES OFFICE: 380 MADISON AVENUE, NEW YORK 17, NEW YORK

General Offices: 135 S. LaSalle St., Chicago 90, Illinois • Offices in all principal cities

OTHER GENERAL AMERICAN EQUIPMENT:—DRYERS • DEWATERERS TOWERS • TANKS • PRESSURE VESSELS

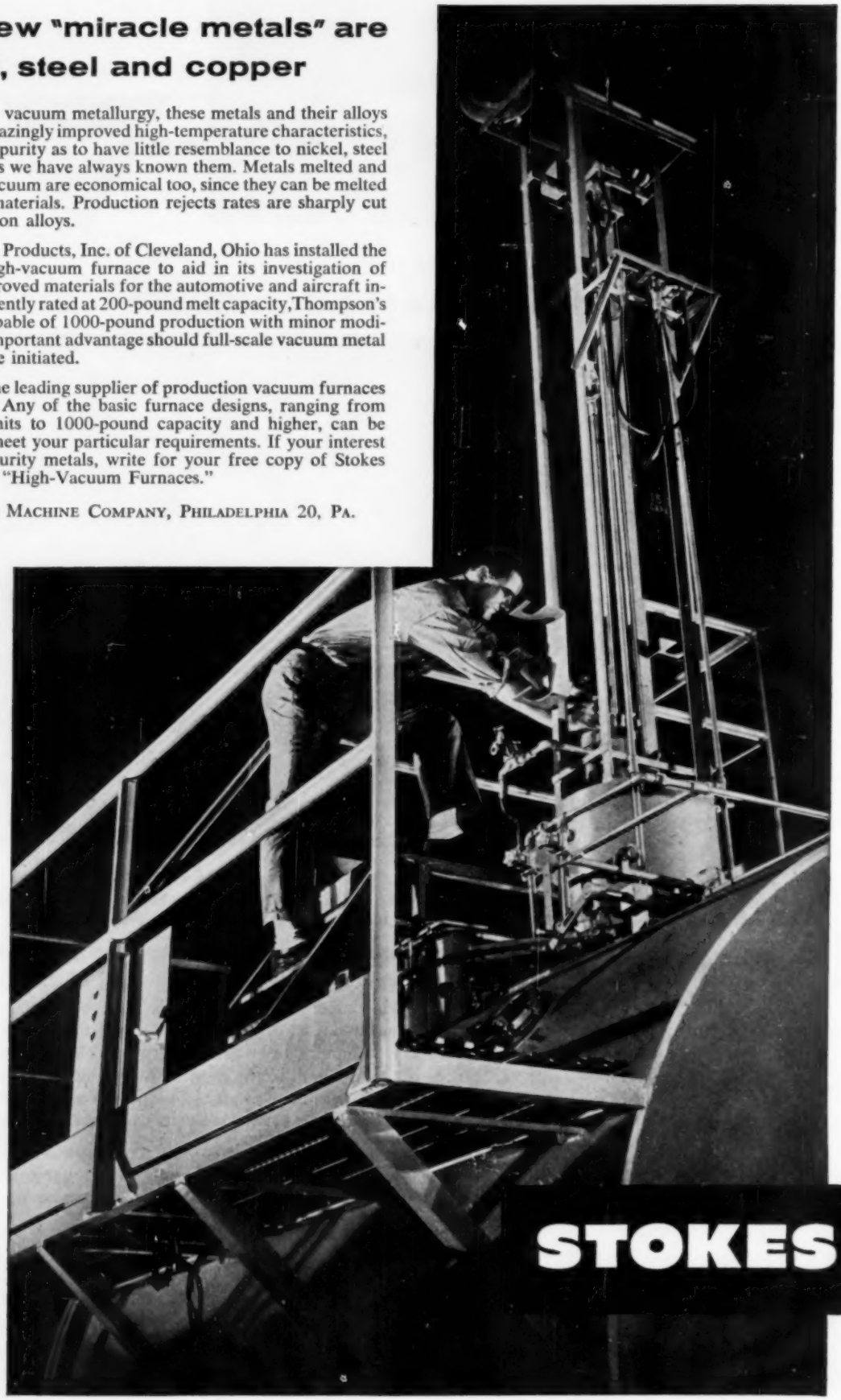
The new "miracle metals" are nickel, steel and copper

Processed by vacuum metallurgy, these metals and their alloys have such amazingly improved high-temperature characteristics, strength and purity as to have little resemblance to nickel, steel and copper as we have always known them. Metals melted and cast under vacuum are economical too, since they can be melted from scrap materials. Production rejects rates are sharply cut on specification alloys.

Thompson Products, Inc. of Cleveland, Ohio has installed the illustrated high-vacuum furnace to aid in its investigation of new and improved materials for the automotive and aircraft industries. Currently rated at 200-pound melt capacity, Thompson's furnace is capable of 1000-pound production with minor modification, an important advantage should full-scale vacuum metal production be initiated.

Stokes is the leading supplier of production vacuum furnaces for industry. Any of the basic furnace designs, ranging from laboratory units to 1000-pound capacity and higher, can be modified to meet your particular requirements. If your interest lies in high-purity metals, write for your free copy of Stokes Catalog 790, "High-Vacuum Furnaces."

F. J. STOKES MACHINE COMPANY, PHILADELPHIA 20, PA.



Corrosioneering News

Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Published by The Pfaudler Co., Rochester, N.Y.

New Pfaudler equipment for atomic plants to be shown at National Atomic Exposition

If you are as wrapped up in this atomic energy business as we are, you recognize many new wrinkles in corrosioneering.

Fabricated titanium units, similar to this reactor, will be in the Pfaudler exhibit (booth 432) at the National Atomic Exposition opening in Cleveland December 10, 1955.

To meet these new needs, Pfaudler is fabricating equipment made of the newest materials of construction, some of which will be on display at the National Atomic Exposition in Cleveland this December.

The titanium reactor shown in our picture is typical. It is designed for pilot plant work. Other units, such as heat exchangers, are underway, using this high-strength metal with its extreme corrosion resistance.

Able to select from a vast variety of standard and custom designs, and able to use glassed steel, stainless steel, titanium, Inconel, Hastelloy and other alloys, Pfaudler has stacked the deck in favor of finding the right solution to your equipment problem – at the lowest possible price.

Before you decide too firmly on equipment to solve your processing problem, write or call Pfaudler to discuss the advantages of several possible solutions.

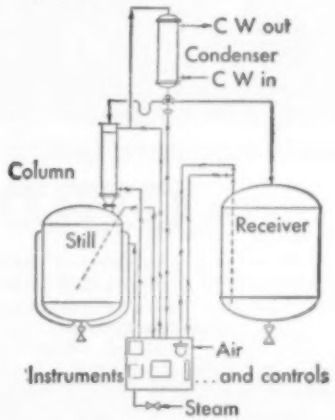
New fractionating assembly is small but highly effective

Here is a small fractionation assembly, in "packaged" form, that can easily put you on the road to solvent recovery without putting too big a crimp in your budget.

It makes use of a glassed steel still and column, to provide maximum corrosion resistance where there is acid present in the batch. This makes the assembly highly practical for such materials as methanol, ethanol, acetone, and ethylene dichloride.

Because the acid remains in the still, the condenser is fabricated from type 316 stainless steel. A glassed steel vacuum receiver is provided for maximum service life, versatility and product purity.

With this assembly, Pfaudler can actually give you a *guarantee* of performance for a specific separation. For example, if you wanted to recover 90% methanol from a charge containing 50% methanol, simple distillation would produce, at best, 65% recovery in a concentration of 60%, and your product would be subject to a certain amount of contamination. To remedy this, Pfaudler is able to guarantee recovery of over 95% of the methanol in the charge, in a concentration of at least 90%, and essentially acid-free.



Small fractionation system is delivered complete with controls

Your Pfaudler representative can answer your specific questions. Call or write him.

This glassed steel reactor at Schenectady Varnish Co. incorporates these new standard features. Note its compact drive support, leaving ample head space for other equipment. Left of drive is a glassed steel column, 18" dia., for calcium chloride; right foreground is 14" glassed steel hopper for adding catalyst.

3,000- to 4,000-gal. glassed reactors now offered in low-cost *standard* designs

Smashing the size barrier, The Pfaudler Co. now fabricates glassed steel reaction kettles in the 3,000- to 4,000-gallon range – as *standard* models.

This use of standard designs saves you money because it eliminates special engineering. And it saves time because it uses stock parts and standard accessories.

Of course, where your requirements are of a special nature, special refinements are available, as well as entirely custom-engineered reactors up to 7,500 gallons.

Space-saving drive support

Drive is rigidly supported on a separable center cover, making other top head openings easily accessible and leaving plenty of space for all nozzles usually required.

Nine openings—various sizes

You get the full advantage of versatile glassed steel because the top head is equipped with nine nozzles, in several sizes, to facilitate adapting the unit to a wide variety of processes.

Other advantages

Offset bottom outlet, efficient jacket provides clean-out ports. Pfaudler agitating nozzles and many other plus values are available in these new standard model reactors. Your Pfaudler representative has all the facts. Write or call him.

for outstanding process performance... make GIRDLER the "contractor of your choice"

WHEN you wish to install a process owned and offered for license by another company, the license usually provides that installation can be made by the "contractor of your choice".

When you make Girdler the "contractor of your choice", Girdler assumes unit responsibility for the entire project. Whether the plant involves petroleum, chemical, plastics materials, food or fertilizer processes, Girdler studies the basic process, custom-designs it to your requirements, engineers and procures equipment, and delivers to you a complete operating plant.

Take advantage of Girdler's broad process experience when you plan process plant expansion or modernization. For information on our complete service call the nearest Girdler office today.

Girdler recently engineered a polyethylene plant for Texas Eastman Company to a process licensed by Imperial Chemical Industries Ltd. Engineering management of Texas Eastman reports: *"The polyethylene plant has operated extremely well, thanks in large part to the very fine job everyone at Girdler did for us. Time and again, we can see where the thought that went into the layout and piping up of equipment has paid off in a very large way. We know that no other group could have done a better job, and it is highly unlikely that anyone would have done as well by us as Girdler".*

The **GIRDLER** Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY
GAS PROCESSES DIVISION: New York, San Francisco
VOTATOR DIVISION: New York • Atlanta • Chicago • San Francisco
In Canada: Girdler Corporation of Canada Limited, Toronto

GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

Chemical Processing Plants	Nitric Acid Plants
Hydrogen Production Plants	Acetylene Plants
Hydrogen Cyanide Plants	Sulphur Plants
Hydrogen Sulfide Plants	Ammonia Plants
Synthesis Gas Plants	Formaldehyde Plants
Carbon Dioxide Plants	Ammonium Nitrate Plants
Gas Purification Plants	Hydrogen Chloride Plants
Plastics Materials Plants	Fertilizer Plants
Carbon Monoxide Plants	Phosgene Plants

Catalysts & Activated Carbon

VOTATOR DIVISION:
Complete Edible Oil Plants;
Continuous Processing Apparatus for:

Chemicals	Salad Dressing
Textile Size	Soup
Shaving Cream	Margarine
Lubricating Grease	Lard
Paraffin Wax	Shortening
Paper Coating	Bakery Ingredients
Resins	Confectioneries
Strained Food	Citrus Concentrates

And other Products

THERMEX DIVISION:
High Frequency Dielectric Heating Equipment Applicable to:

Rayon Cake Drying	Foam Rubber Jelling and Pre-Heating
Cellulose Sponge Drying	Foam Rubber Pre-Heating for Cure
Foam Rubber Drying	Plastic Preform Pre-Heating
Automotive Trim Heat-Sealing	Foundry Core Baking
Vinyl Foam Fusing	Wood Bonding
Plastisol Fusing	

whatever your interests

PUMPS ☒

LIQUID METALS ☒

EVAPORATION ☒

NUCLEAR ENGINEERING ☒

TECHNICAL SOCIETIES ☒

BIOCHEMICAL ENGINEERING ☒

BUBBLES & DROPS ☒

it's time

TO MAKE *FINAL* PLANS FOR **DETROIT**

Nov. 27-30 A.I.Ch.E. ANNUAL MEETING

Leon Chrzan | Ethyl Corp.

Historic, industrial, cosmopolitan Detroit is waiting for you. All you've got to do now is pack the bags, take the wife (and family, Detroit will be an experience for the children), and try to make up your mind what you want to see and do most among all the things Detroit has to offer.

If it's football you like get there by Thanksgiving for the Lions-Packers game. Hockey might be your interest or the symphony, the theater, the big films, plant tours, museums, or just plain good eating and drinking in the hundreds of spots a big city has to offer.

But let's be realistic, you're coming to the Annual Meeting, and there's going to be so much of that you'll really have to come early and stay late if you want to get a good chunk of Detroit as well.

Nuclear First

The broad, jam-packed, technical program will kick-off on Sunday afternoon, the 27th, with a wide-open symposium on Experiences in Nuclear Engineering Education. Under the leadership of Nuclear Engineering Division chairman R. P. Genereaux, Du Pont, this is going to be a short-talk, long-discussion session (10-minute limit on papers), where everyone is going to be heard, and industry's views on education for nuclear engineering will get a big play. Main theme is "experience," what has been done and how well it was done, facts not speculation. Basic problem in nuclear engineering education is how to teach what industry is going to need, and to whom? A. McCullough of Monsanto pointed out at the Lake Placid meeting, ". . . if we expect to utilize the real potentialities of nuclear energy in the future, the chemical engineers must show us how we can handle this . . . economically and safely." The only question now is how best to teach the chemical engineer the science of nuclear engineering.

Should nuclear be separate from chemical engineering or an integral part. Is it a subject for the graduate chemical engineer, or should it be a special program on the undergraduate level, or should it be worked into the normal chemical engineering. We need nuclear engineers, where are we going to get them, how shall we best teach them? From experience comes wisdom. At this symposium, A. Sesonske, Purdue, C. F. Bonilla, Columbia, and O. E. Dwyer, Brookhaven National Laboratory, will give details of three different aspects of nuclear teaching methods already done, one graduate, one undergraduate, one doctoral. J. J. Martin will discuss physical facilities for radiation studies at University of Michigan, and R. M. Boarts, Tennessee, will consider the broader aspect of "Nuclear Education and The Universities" in general.

Liquid Metals

The tendency to adopt something of a "hands-off" attitude toward liquid metals has now been largely dispelled by

DETROIT

(Continued)

extensive application in nuclear engineering, and the broad potential of liquid metals is becoming apparent. Much has been done on the nuclear aspects of the use of liquid metals, but the chemical engineering has tended to lag. C. F. Bonilla has set out to remedy this in his liquid metals symposium.

The problems involved in heat transfer, a major use of liquid metals, will be considered in the light of much new work, some at the Naval Research Laboratory, in a paper from the Laboratory titled "Thermal Conductivity of Liquid Metals." One of the important parts of this paper is a new, improved method of predicting the thermal conductivity of liquid metals from their electrical conductivity and other physical properties.

Heating by contact between immiscible liquids of different density in a column is a relatively unexplored field. A paper by Pierce *et al.* goes into this matter in considerable detail. Turning to mass transfer in liquid metal systems, Dunn *et al.* points out how little has ever been done to analyze liquid metal corrosion and other mass transfer processes by unit operations procedures. In their paper this is precisely what they will do with extremely important and interesting results.

There is little doubt that one of the more important liquid metals today is sodium. Key heat transfer medium in nuclear reactors, Na and NaK alloys will doubtless find accelerated industrial use. What do you know about it? Very little we imagine. Well Thompson and Garelis are going to give a detailed study of this metal's physical and thermodynamic properties. The final paper in this varied program is the first detailed survey of high temperature loop techniques and experiences by Fisher and Winders.

Belle Isle: Detroit Boat Club (foreground), and a public park with zoo, golf course, swimming beach.

Biochemical Engineering

Biochemical engineering is one of the newest fields to benefit from the ministration of the chemical engineer ($300 million sales/yr. for biochemicals and for fermentation products). Recognition of the special problems involved for the engineer in biochemical processes is only beginning to come to the fore, the whole industry in the process of metamorphosis from art to science. Where rule of thumb and experience has held sway, the engineer is now going in and working from fundamentals upward.

Tools are vitally needed. A University of Michigan team offers one such tool for the study of the unit operation of fermentation—a major industrial process. Their method, the measurement of acid produced by homofermentative lactobacilli at controlled *p*H, offers much promise in this area.

Another vital area of biochemical engineering is the biological treatment of industrial waste. Two papers will consider this problem, which is perhaps one of the least understood mechanisms in modern engineering. One paper, by Roth, Hidge and Lively, Camp Detrick, Md., concerns laboratory study techniques, while the second, by W. W. Eckenfelder, Jr., Manhattan College, takes up the practical, industrial factors involved in biological waste treatment.

Lightfoot examines countercurrent separations in fixed beds, showing clearly that biochemical operations involve all the familiar unit operations of chemical engineering. Finally, R. K. Finn, Cornell, turns to the basic matter of educating the engineer for biochemical engineering. What is being done, how, and why will be discussed.

The Society

There is no better time than at the Annual Meeting to take a step backwards and get a look at ourselves. This, of course, is the purpose of J. B. Phillips' symposium on the place and value of the technical society in industry. Looking at us from the point of view of industry, G. L. Royer, Cyanamid, and A. Monsaroff, Monsanto Canada, give a strong vote of confidence to the technical society. Royer sees big advantages to the company in having its members in technical societies. Much has been said these last few years on *executive* development, but perhaps more important for the engineer is *professional* development. The engineer is pre-eminently a professional man, and his standing in his profession is of the utmost importance both to him and to his company. Professional standing means in essence a man's reputation *outside* his company, as an engineer not as a valued employee of a reputable company. It is within the technical society that a man has his greatest opportunity for professional development and professional recognition.

Looking from the viewpoint of the technical society itself, F. J. Van Antwerpen, A.I.Ch.E. secretary, is going to analyze the principle ways in which the technical society feels it can help the engineer, his company, and the industry in general. At the same time, Van Antwerpen wants to know how well the society is meeting industry and individual needs, what new projects and efforts should be undertaken, so come prepared to get your pet ideas on the floor. All is not always well, however, and Van Antwerpen is going to take up the problem of why the technical society has to *sell* itself to industry.

Engineering Administration Building, General Motors.

Unit Operations

The unit operations are still the backbone of chemical engineering and three symposia will consider two of them that are growing in importance every year: Evaporators, and the mechanics of bubbles and drops.

(*Continued on page* 60)

TECHNICAL PROGRAM

SUNDAY, NOVEMBER 27, 1955

SESSION 1—EXPERIENCES IN NUCLEAR ENGINEERING—R. P. Genereaux, presiding.

A One Semester Introductory Course, A. Sesonske, Purdue Univ.

The Two-Term Graduate Survey Course in Nuclear Engineering, C. F. Bonilla, Columbia Univ.

Undergraduate Chemical Engineering Problems Using Nuclear Engineering Information, J. O. Maloney, Univ. of Kansas.

Nuclear Education and the Universities, R. M. Boarts, Univ. of Tennessee.

Radiation Facilities at the University of Michigan, J. J. Martin, Univ. of Michigan.

Doctoral Research In Nuclear Engineering at the Brookhaven National Laboratory, O. E. Dwyer, Brookhaven National Laboratory, Upton, N. Y.

MONDAY, NOVEMBER 28, 1955

SESSION 2—GENERAL PAPERS (Simultaneous with Session 3)—S. A. Miller, presiding.

Single Phase Blending of Liquids, E. A. Fox and V. E. Gex, Procter & Gamble Co.

Agitation of Non-Newtonian Fluids, A. B. Metzner and R. E. Otto, Univ. of Delaware.

Use of Electronic Analogs In Studies of Reaction Kinetics and Reactor Design, J. A. Beutler and J. B. Roberts, Du Pont.

Rate Studies In Tubular Reactors, H. E. Hoelscher and Eric Weger, Johns Hopkins Univ.

The Rate of Nitration of Benzene With Mixed Acids, R. D. Biggs and R. R. White, Univ. of Michigan.

SESSION 3—EVAPORATORS—W. L. Badger, presiding.

Some Fundamental Considerations in Evaporator Design, T. G. Bernhardi, Swenson Evaporator Co., Harvey, Ill.

Selection and Application of Evaporation Equipment, M. M. Coston, Rodney Hunt Machine Co., and E. E. Lindsey, Univ. of Mass.

Cost Factors in Evaporator Design, W. D. Kohlins and H. P. Englander, Buflovak Equipment Division, Blaw Knox Co.

A Modern Salt Evaporator, R. B. Richards, International Salt Co.

TUESDAY, NOVEMBER 29, 1955

SESSION 4—THE TECHNICAL SOCIETY, ITS PLACE AND VALUE IN INDUSTRY—J. B. Phillips, presiding.

Should Industry Encourage Technical Society Membership? G. L. Royer, American Cyanamid.

The Importance of a Technical Literature, J. J. McKetta, Jr., Univ. of Texas.

Advantages of Society Participation to the Company, A. Monsaroff, Monsanto Canada, Ltd.

What the Technical Societies Have to Offer, F. J. Van Antwerpen, A.I.Ch.E.

SESSION 5—STANDARDIZATION OF CENTRIFUGAL CHEMICAL PUMPS (Simultaneous with Session 4)—C. J. B. Mitchell, presiding.

Introduction, C. J. B. Mitchell, Du Pont

Mechanical Design of Centrifugal Pumps From Shaft Deflection Measurements, D. S. Ullock, J. A. Reynolds and T. W. Hudson, Carbide and Carbon Chemicals.

The Dimensional Standardization of Centrifugal Pumps, D. C. Brand, Monsanto.

Standardization of Centrifugal Chemical Pumps From the Viewpoint of the Manufacturer, M. L. Murdock, Allis-Chalmers Mfg. Co.

SESSION 6—LIQUID METALS IN CHEMICAL INDUSTRY—C. F. Bonilla, presiding.

Thermal Conductivity of Liquid Metals, C. T. Ewing, J. A. Grand, R. E. Seebold, and R. R. Miller, Naval Research Laboratory.

Heat Transfer and Fluid Dynamics In Mercury-Water Spray Columns, R. D. Pierce, Babcock & Wilcox, O. E. Dwyer, Brookhaven National Laboratory, J. J. Martin, Univ. of Michigan.

Mass Transfer in Liquid Metal Systems, W. E. Dunn, Du Pont, C. F. Bonilla, Columbia Univ., C. Ferstenberg, Du Pont, and B. Gross, Dugway Proving Grounds.

High Temperature Loop for Circulating Liquid Metals, R. W. Fisher, and G. R. Winders, Iowa State College.

The Physical and Thermodynamic Properties of Sodium, G. W. Thompson and E. Garelis.

SESSION 7—GENERAL PAPERS (Simultaneous with Sessions 6 and 8)—J. L. York, presiding.

Enthalpy of Hydrocarbon Mixtures, L. N. Canjar and V. J. Peterka, Carnegie Institute of Technology.

The Theorem of Corresponding States Applied to Saturated Liquids and Vapors, M. Hobson and J. H. Weber, Univ. of Nebraska.

Mass and Heat Transfer to Single Spheres and Cylinders at Low Reynolds Numbers, S. K. Friedlander, Columbia Univ.

Mass Transfer Studies in an Agitated Vessel, A. I. Johnson and Chem-Jung Huang, Univ. of Toronto.

Separation of Liquids by Thermal Diffusion, J. E. Powers and C. R. Wilke, Univ. of California.

SESSION 8—BIOCHEMICAL ENGINEERING (Simultaneous with Sessions 6 and 7)—H. O. Halvorsan, presiding.

Acid Production by Homofermentative Lactobacilli at Controlled pH as a Tool for Studying the Unit Operation of Fermentation, L. L. Kempe, R. A. Gillies and R. E. West, Univ. of Michigan.

An Application of the Sulfite Method of Determining Oxygen Uptake in the Study of Aeration Requirements of Certain Bacteria, N. G. Roth, H. M. Hodge, and D. H. Lively, Camp Detrick, Frederick, Md.

Process and Equipment Design of Aeration Systems for Biological Waste Treatment, W. W. Eckenfelder, Jr., Manhattan College.

Counter-Current Separations in Fixed Beds: Linear Isotherms and Free Bands, E. N. Lightfoot, Univ. of Wisconsin.

Training Engineers for the Biochemical and Fermentation Industries, R. K. Finn, Cornell University.

WEDNESDAY, NOVEMBER 30, 1955

SESSION 9—GENERAL PAPERS—G. F. Jenkins, presiding.

A Study of Retention Time in a Rotary Dryer, F. Miskell, Allis-Chalmers Mfg. Co., and W. R. Marshall, Jr., Univ of Wisconsin.

Performance of an Internally-Baffled Multistage Extraction Column, E. G. Scheibel, Hoffmann-La Roche, Inc.

Effecting General Cost Reductions and Reducing Industrial Waste Problems by Water Management, K. S. Watson, General Electric, Co.

Flow Distribution in Manifolds, A. Acrivos, Univ. of California, B. Babcock, Univ. of Wisconsin, and R. L. Pigford, Univ. of Delaware.

Multicomponent Material-Transfer Calculations for Solvent Extraction of Uranyl Nitrate, A. F. Lane, Jr., H. R. Lehman, Barney Rubin, and T. Vermeulen, Univ. of California.

SESSION 10—MECHANICS OF BUBBLES AND DROPS (Simultaneous with Session 9)—R. C. Kintner, presiding.

Formation of Bubbles at Submerged Orifices, J. C. Bryan and H. J. Garber, Univ. of Tennessee.

Effect of Turbulence on Drop Size for an Oil-Water Dispersion, P. H. Roy and J. H. Rushton, Illinois Institute of Technology.

Light Transmittance at a Measure of Interfacial Area in Liquid-Liquid Dispersions, V. C. Trice, and W. A. Rodger, Argonne National Laboratory.

Effect of Wall Proximity on the Rate of Rise of Single Air Bubbles in a Quiescent Liquid, Sieji Uno and R. C. Kintner, Illinois Institute of Technology.

SESSION 11—MECHANICS OF BUBBLES AND DROPS APPLICATIONS (Simultaneous with Session 12)—H. J. Garber, presiding.

A New Technique For Drop-Size Distribution Determinations, A. P. Roy Choudury and W. F. Stevens, Northwestern Technological Institute.

Bubble Studies for Single-Holed Perforated Plates, A. I. Johnson, D. G. Robinson, and C. P. Michellepis, Univ. of Toronto.

Mechanism of Heat Transfer to Liquid Drops, R. V. McDowell and J. E. Myers, Purdue Univ.

Some Mass Transfer Effects Inside Drops in a Miniature Liquid-Liquid Spray Tower, F. P. Pike, W. T. Withers, Jr., and K. O. Beatty, Jr., North Caroline State College.

SESSION 12—GENERAL PAPERS (Simultaneous with Session 11)—J. Y. Oldshue, presiding.

Multicomponent Distillation—Calculation of Minimum Reflux, J. B. Bachelor, San Gabriel, Cal.

Evaporation of High Velocity Drops, E. S. Starkman, Univ. of California.

Studies in Falling Film Boiling Heat Transfer, C. M. Bosworth, Carrier Corp.

Fluidized Bed Heat Transfer—A Generalized Correlation, Chin-Yung Wen, West Virginia Univ., and Max Leva, Pittsburgh, Pa.

Design Correlations for Aluminum Foil Rupture Disks, P. B. Stewart and R. T. Fox, Jr., Univ. of California.

PLANT TRIPS

MONDAY, NOVEMBER 28, 1955

M-1 International Salt Company 6:30 P.M.
M-2 Scott Paper Company 1:00 P.M.
M-3 Ford Motor Company 1:00 P.M.
M-4 Polymer Corporation, Limited, Sarnia 12:00 Noon
M-5 Stroh's Brewery 12:30 P. M.
M-6 Hiram Walker and Sons, Limited, Windsor 1:00P.M.
M-7 Sharples Chemicals, Incorporated 1:00 P.M.
M-8 Rinshed-Mason Company 1:00 P.M.
M-9 Pennsylvania Salt Manufacturing Company 1:00P.M.
M-10 Greenfield Village and Ford Museum 1:00P.M.
M-11 Great Lakes Steel Corporation 1:00 P.M.
M-12 General Motors Technical Center 1:00 P.M.

TUESDAY, NOVEMBER 29, 1955

T-1 International Salt Company 6:30 P.M.
T-2 Wyandotte Chemical Corporation 1:00 P.M.
T-3 Ford Motor Company 1:00 P.M.
T-4 Ethyl Corporation, Research Laboratories 1:00P.M.
T-5 Socony-Vacuum Oil Company 1:00 P.M.
T-6 Goebel Brewing Company 1:30 P.M.
T-7 Parke-Davis and Company 1:30 P.M.
T-8 Sharples Chemicals Incorporated 1:00 P.M.
T-9 Greenfield Village and Ford Museum 1:00P.M.
T-10 General Motors Research Center 1:00 P.M.

THURSDAY, DECEMBER 1, 1955

Th-1 Dow Chemical Company, Midland Plant

LADIES PROGRAM

Morning coffee hours are planned each day.

MONDAY, NOVEMBER 28, 1955

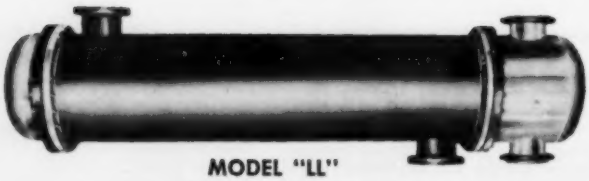
Special Luncheon with entertainment.
Trip to Greenfield Village or Ford Motor Company.

TUESDAY, NOVEMBER 29, 1955

Morning tour of Civic Center and visit to Windsor, Canada.
Lunch at Engineering Society of Detroit.
Brief tour of Detroit Institute of Arts, Detroit Historical Museum, and the International Institute.

WEDNESDAY, NOVEMBER 30, 1955

Visit to fabulous Northland Shopping Center.



MODEL "LL"
MULTI-PASS COOLER

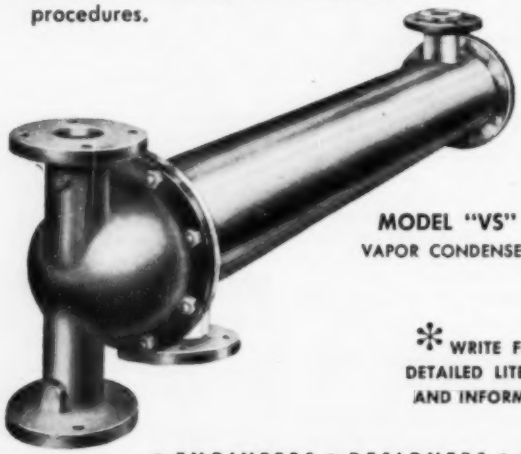
DOYLE & ROTH
standard stainless steel
HEAT EXCHANGERS

designed . . .
to meet the exacting requirements of the petroleum, chemical and petro-chemical industries.

standardized . . .
to insure lower prices, fast delivery.

D & R passes on to you the economies accruing from its standardization program. Starting with engineering and following through on construction, economies are substantial. Materials are purchased to rigid specifications and standard components are stocked. ASME standards govern fabricating procedures.

MODEL "VT"
VERTICAL THERMOSYPHON REBOILER



MODEL "VS"
VAPOR CONDENSER

✻ WRITE FOR DETAILED LITERATURE AND INFORMATION

• ENGINEERS • DESIGNERS • FABRICATORS

DOYLE & ROTH Manufacturing CO. INC.

136-50 TWENTY-FOURTH STREET, BROOKLYN 32, N. Y.

DETROIT *(Continued)*

W. L. Badger, dean of evaporator specialists, conducts the symposium on his specialty, covers four angles. T. G. Bernhardi, Swenson Evaporator Co., is going to analyze the fundamental considerations in evaporator design. Evaporators are no longer simple, invariable pieces of equipment. For any practical discussion the evaporator cannot be considered *in toto* any longer, subdivision is called for. Bernhardi is going to tackle that problem, has come up with a method of analysis whereby the engineer can recognize the various common denominators of evaporator design, and can apply and extend these common denominators in specific cases.

In any unit operation the selection of equipment is a basic function of the engineer. Coston, Rodney Hunt, and Lindsey, Univ. of Mass., basing their paper on the premise that selection of an evaporator is an integration of solution characteristics, evaporator characteristics, and economics, take each factor point by point, using specific cases as illustration. Think it's easy? You may be surprised by Coston and Lindsey. Taking the ball from there, Kohlins and Englander, Blaw-Knox, carry on into a more detailed study of the vital cost problem, showing the specific areas for cost reduction in evaporator design and specification, how and why! As a specific demonstration of the changing picture in evaporation, R. B. Richards, International Salt, will present, in detail, the concept, design, and application of a modern salt evaporator.

In any processes involving distillation, evaporation, absorption, aeration, mixing, liquid-liquid extraction, and other operations, the mechanics of bubbles and drops come into sway. Old stuff? Hardly, no field has shown more remarkable work in recent years, and few fields are questioning long-accepted principles as much as this one. In fact so much is being questioned nowadays that basic research into the nature and behavior of bubbles and drops is the order of work now.

So important to engineering is this field that two symposia are being conducted at Detroit. The first, under R. C. Kintner, takes up the more theoretical aspects, will investigate many new doubts that have been cast on the time-honored concepts. There are questions raised on the pattern of flow within the small sphere, ellipsoid, or cap. Are the equations currently used for the measurement of interfacial tension by the drop volume method valid in the light of new observations? Are we really clear in our use of such terms as "surface viscosity" and "dynamic surface

(*Continued on page 62*)

A NEW PRINCIPLE

IN RADIATION DETECTION!

THE LIBRASCOPE

BIC-2

RADIATION DETECTOR

FEATURES:

- Rugged, sealed unit
- Shock and Moisture-Proof
- Accurate, Simple Operation
- Carried by Belt or Shoulder Strap
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THE BIC-2 *provides* LOW COST PROTECTION *for Industrial Use and* CIVILIAN DEFENSE DISASTER TEAMS

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The Librascope BIC-2 is a compact, inexpensive device for measuring radiation rate quickly and accurately in amounts from .05 to 50 Roentgens per hour. The operation of this instrument is based on a principle developed in Librascope's research laboratories; the Balanced Ionization Chamber.

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INDUSTRIAL NEWS

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DETROIT *(Continued)*

tension?" These and many more aspects of the latest research will be thrashed out at Detroit. The second symposium concerns itself more with the applications of the mechanics, is under the leadership of H. J. Garber.

Pumps—How Soon Standardized

It has been estimated that proposed standards for centrifugal chemical pumps will result in savings of some $7 million annually to the chemical industry. With this fact staring us in the face, C. J. B. Mitchell is going to preside over a forum type of symposium which will thoroughly air the views of both consumer and supplier. Since a Sectional Committee of the American Standards Association is already underway on a study of the problem, there will certainly be a lot of interested parties present. Papers by Ullock of Carbide & Carbon, and Brand of Monsanto will give the technical and users' viewpoints, the factors involved for the users of these pumps. Speaking for the pump manufacturers, M. L. Murdock, Allis-Chalmers, has rounded up the opinions and recommendations of many pump manufacturers, gives a consensus, not simply his own or his company's view. All in all this session should be a lively and productive one.

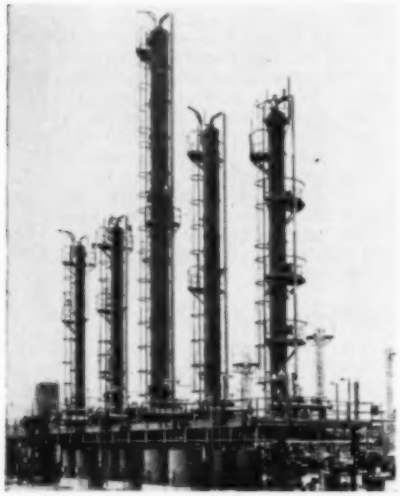
General

As always, some of the most important papers will be in the General Technical Sessions. There will be four of these in all, and subject matter runs the gamut. Instrumentation gets in the act in a paper by Beutler and Roberts of Du Pont, "Use of Electronic Analogs in Studies of Reaction Kinetics and Reactor Design." There are papers on rate studies, on mass and heat transfer, on problems of liquids and non-Newtonian fluids. On the less technical side there is Watson's paper from General Electric on "Effecting General Cost Reductions and Reducing Industrial Waste Problems by Water Management."

This can only scratch the surface of what is in the general sessions, in fact we have only scratched the surface of the whole technical program. Without doubt this is one of the most inclusive, detailed, and important technical sessions of the year. It should be. This is the Annual Meeting. And don't forget, in all the time you have left over from the technical sessions, from Detroit and its many-pleasured attractions, there will be a lot of informal talking to do, committee work to investigate, the banquet to attend, and . . . well, what's the use? We could never tell you all there is to do, could we? The only thing you can do is what we're going to do—be there!

Work of constructing the first large scale isophthalic plant is entering its final phase, start-up is expected for late this year. Costing more than $7 million, the plant is being erected by H. K. Ferguson Co. for the Standard Oil Co. of California at Standard's Richmond refinery, near San Francisco.

The plant has been designed by Standard engineers to turn out 50 million pounds annually of the outstanding new raw material for the plastics and surface coating industries. □



World's first full-scale nitroparaffins production facilities are now on-stream at Commercial Solvents' Sterlington, La., plant. The four basic compounds produced are: Nitromethane, nitroethane, 1-nitropropane, and 2-nitropropane. All are highly versatile raw materials for chemical processes. □

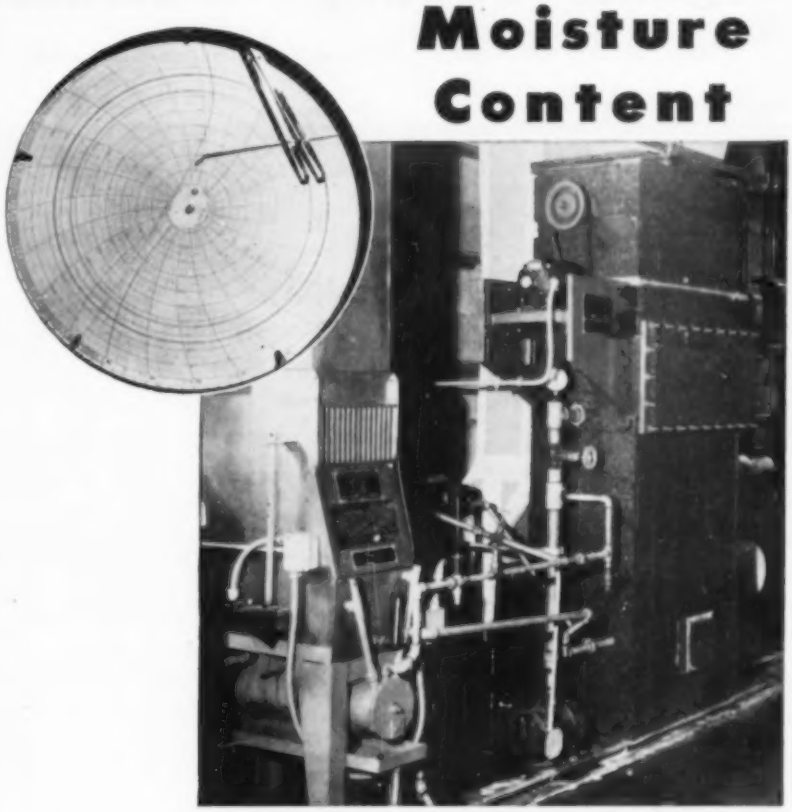
A 15% expansion is underway at Phillips Chemical Co.'s Plains copolymer plant near Borger, Texas. Reason: Increased demand for the company's synthetic rubber. □

At the new Guanica, Puerto Rico, plant of Gonzales Chemical Industries, Inc., 42 thousand tons of anhydrous ammonia per year will be produced. Part of this will be sold as such, and the balance will be converted to aqueous ammonia, sulfuric acid, ammonium sulfate, and some other materials for agricultural and industrial use.

The plant was designed and will be built by the Lummus Co. □

Expansions plans at the vinyl acetate facilities of Carbide and Carbon Chemicals at Texas City, Texas, will double the plant's output. The multi-million-dollar project is expected to be finished by the Fall of 1956, will substantially increase total national production. □

EXACT CONTROL of Moisture Content



. . . To Improve Your Product or Protect Your Materials or for Processes or Tests

● This Niagara Air Conditioning Method dries air directly and measurably, using a moisture-absorbing liquid spray. It makes humidity control a separate function from lowering or raising temperatures and gives you precise control with thermostats alone; no moisture-sensitive devices are needed. You have simpler, more trustworthy, less expensive control instrumentation. Niagara precise-control installations have the best record for reliability.

Niagara Air Conditioning provides you with any temperature and relative humidity you need. Using "Hygrol" absorbent, it is not expensive to operate, saving the refrigeration commonly used to condense moisture and making re-heat unnecessary in most cases. It gives large capacity with compact, easily-maintained equipment. Ask for Descriptive Bulletins #112 and #121. Address Dept. EP.

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Organic Coatings Indicator Chart (Part III)

Kenneth Tator, Kenneth Tator Associates, Coraopolis, Pa.

ZINC-RICH COATINGS

These are coating compositions which are formulated with an extremely high loading of finely divided sacrificial metal, usually zinc, and which are designed to provide galvanic protection to the base of steel. Only sufficient organic vehicle is incorporated to provide a binder for the metallic particles, adequate adhesion, and practicability of application. For maximum effectiveness, the sacrificial metallic particles should be in direct electrical contact with the basic steel, hence sandblasting is an essential requirement for service preparation. Two general types of binders are available: organic and inorganic. Organic binders may be of chlorinated rubber, vinyl, oil base, or methacrylate; inorganic vehicles are usually sodium silicate. In the case of the latter, water solubility is obtained by ionizing sufficient of the zinc particles to form a zinc silicate by heating the applied coating or washing it with acid.

Chemical resistance of these coatings is limited by the chemical resistance of zinc; solvent and temperature resistance by that of the binder or vehicle. Weathering and moisture resistance is generally excellent and approaches that obtained by hot dip galvanizing.

SILICONES

Potentially these include literally hundreds of generic types within this class, but those currently in general use for industrial protection are notable primarily for their resistance to high temperatures, and a moderate resistance to chemical vapor and spillage conditions. Predominant current use is as stack coatings.

Thermosetting Coatings

This classification includes those thermosetting resins which must be polymerized during or after application by baking or by catalyst addition. These coatings along with silicate-bound zinc-rich coatings, possess the highest resistance to solvent exposures and elevated temperatures. Surfaces presented are usually tough, and of glass-like smoothness and gloss. With the exception of the epoxies, colors are normally restricted to darker hues.

PHENOLICS

Should not be confused with phenolics previously discussed under the Oil Base group. The thermosetting phenolics do not contain drying oil modifications. Normally available only in darker colors, these materials exhibit excellent resistances to organic solvents, organic and inorganic acids, and elevated temperatures up to and sometimes exceeding 350° F. Alkali resistance is poor.

FURANES

These materials possess in general the same properties and resistances of the phenolics, but better resistance to oxidizing and alkaline exposures.

EPOXIES

Should not be confused with the epoxy esters. Generally possess the same advantages previously cited for the phenolics and furanes, but with better resistance to alkaline exposures. Possess the advantage of being light-colored.

Rubbers

Included are only the vulcanizable rubbers.

NEOPRENE

Only neoprenes have found acceptance as industrial coatings. Currently available as compounded neoprene solvent solutions and as neoprene latex. Latex is in wide and successful use as linings for equipment and tank cars for caustic service. Owing to their nature, they possess greater moisture susceptibility than the solvent neoprene solutions, and thus the latter are usually preferred for weathering, moist, and acid services.

These materials have relatively high material and application costs which, however, are adequately offset by a greatly extended protective durability, and great universality of resistance. The neoprenes possess good resistances to both alkaline and acidic exposures, adequate resistance to many organic solvents and moderate resistance to elevated temperatures.

The solvent solutions are currently available as one- or two-package coating compositions, with the greatest resistances being exhibited by the catalyzed two-package systems, although adequate resistances for maintenance purposes are obtained with the less complicated application of the one-package materials. Color availability is currently limited, with best chemical resistance obtained from black.

PLASTIC MATERIALS

In this general classification are included those materials which are softened by heat and which if deposited by evaporation of solvent can at any subsequent time be redissolved by the same solvents used in the original formulation. These plastic materials normally possess good resistance both on acid and alkali exposures, poor resistance to continuous elevated temperatures and to the action of organic solvents.

CHLORINATED RUBBER

Of all the synthetic protective coatings, chlorinated rubbers within the formulations typically available, have greatest ease of application and in this respect approach the oil base materials. Available in full color range. Available in a wide range of formulations; many, because of their deficient chlorinated rubber-resin content, possess little if any of the known properties of chlorinated rubber. With present methods of formulation identification it is difficult for the prospective user to be sure that he is procuring material which will provide characteristic chlorinated rubber performances.

Reasonably resistant to inorganic acids, affected by sunlight and weathering, and better than average resistance to alkalis. A preferred protective coating for concrete and masonry construction.

VINYLS

The vinyl in widespread industrial maintenance use is the copolymer-chloracetate. These materials possess a rather wide range of resistances, both on the acid and alkali sides. They are available in the entire color range. Conventional vinyl maintenance coatings require special techniques in their application, such as double spray passing or hot spray, in order to attain economically durable thicknesses. Newly introduced vinyl mastics permit the building of adequate thicknesses without these special procedures.

Polyvinyl acetate dispersions are currently being introduced and these show excellent potentialities as coatings for concrete and masonry and as nonbleeding coatings for the coloration of bitumins and insulation.

POLYETHYLENE

This highly chemical resistant material is available as a protective coating only in a hot-melt application. The physical characteristic of the film suggests a leather, rather than a rubber or a conventional protective coating film. Thicknesses are in the range of 1/16 to 3/32 in. as by current methods of application, film continuity cannot be assured below these thicknesses, and the film is liable to be brittle and to develop severe shrinkage and stress-cracks when applied at greater thicknesses. Uniform and strong adhesion to a base of steel is not dependable at this time.

BITUMIN

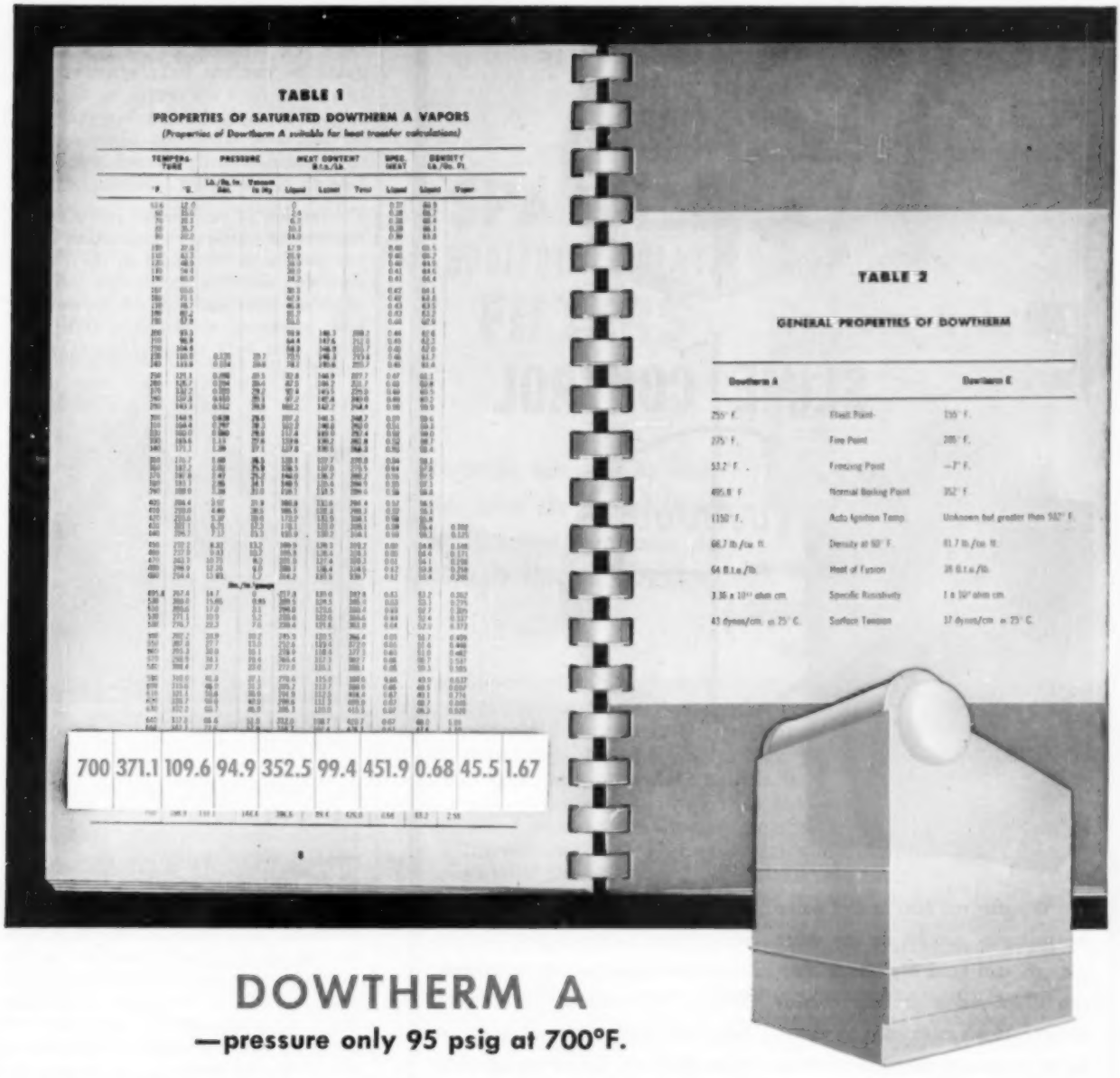
Bitumins may be divided into two basically different types: asphalts and coal tars. These are sometimes treated as equivalents in application, with disastrously unsatisfactory results, as the properties of each are not interchangeable and each has its preferred use. Both are available either as solvent cut-backs or as water emulsions In general, the water emulsions are less resistant than the solvent-cut materials, as they are more susceptible to moisture. Each is also available as straight solutions or as fibrated mastics. In general, the straight solutions apply too thinly for durable protection, and best results are obtained with the heavier fibrated mastics.

Optimum protective dry-film thicknesses for these materials are of the order of 1/16 to 1/8 in. These materials have poorer compatibility with other types of coating materials and hence no surface should be committed to these materials unless there is reasonable assurance that protection of such surfaces will be continued in the future with these material types. The materials are basically black.

(*To be continued*)

No. 50

Pressure Problems In Process Heat?



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—pressure only 95 psig at 700°F.

Taking a page from the Dowtherm Handbook—high temperatures *do not* create high pressures when you use the modern heat transfer medium, Dowtherm®. The savings are obvious in less expensive, thinner walled equipment that occupies far less space.

When Dowtherm is used, heat can be controlled with *fraction-of-a-degree accuracy* by simple pressure regulation. Dowtherm provides low-pressure, high-temperature heat, extending the advantages of vapor-phase heating to much higher temperatures. The extraordinary thermal stability of Dowtherm makes it a natural for those applications demanding liquid-phase heating.

Your foresight in investigating Dowtherm may provide your company's competitive edge of the future. You'll find all the facts in the "*Dowtherm Handbook*", a valuable technical guide of process heat information. A request on your letterhead will bring it to you promptly. THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 726A-2.

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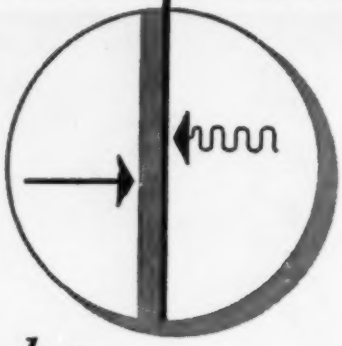
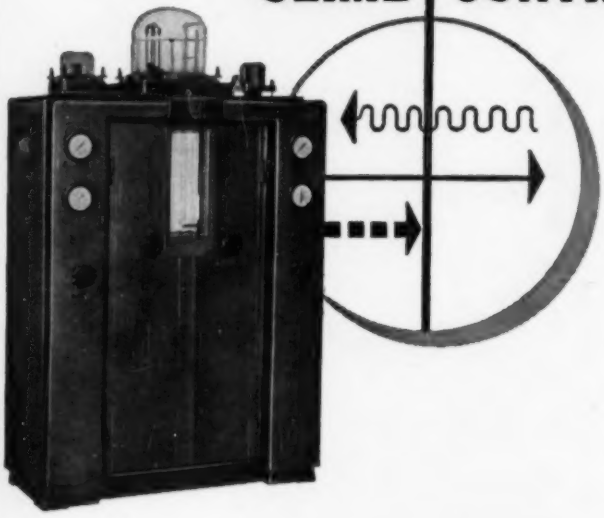


Be sure you have

SLIME | CONTROL



Whether you heat or cool water for make-up, process or any other use, you will need Wallace & Tiernan Chlorination to help combat slime problems introduced by water-borne bacteria or air-borne bacteria.

With slime control equipment designed for any need, built for lasting and dependable service, highly accurate and backed by over 40 years of successful application experience, Wallace & Tiernan Chlorination can help you increase the efficiency of your plant and cut operating costs. For further information write our Industrial Division.

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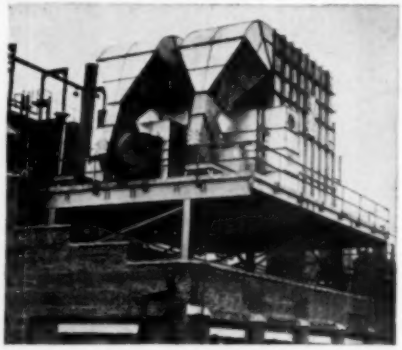
CD-39

INDUSTRIAL NEWS

Modern cresylic acid refinery is being built in Newark, N. J., by Pitt-Consol Chemical Co., a newly formed subsidiary of Pittsburgh Consolidation Coal Co. □

The sulfur recovery plant at Union Oil's Los Angeles Refinery is finally going to operate fully after waiting two years for a complete operating permit. The problem was air pollution, officials now agree that Union's pollution control efforts are not only satisfactory but excellent. □

Prevention of organic air pollution by the use of catalytic combustion units has proven so successful at the Frankfort, Pa., works of the Barrett Division of Allied Chemical that the company is now preparing to install a third and larger unit built by Catalytic Combustion Corp.



The problem at Frankfort was residual organic matter in the off-gas from the manufacture of phthalic anhydride. The Catalytic units, employing a platinum catalyst on a supporting medium of nickel-chromium alloy, oxidize the residual matter to carbon dioxide and water, completely removing the air pollution. □

Purchase of a group of five buildings and ten acres of land from the Crucible Steel Co., is the latest step in the expansion program of Rem-Cru Titanoum, Inc., a jointly-owned company of Crucible and Remington Arms Co., a Du Pont subsidiary.

The buildings will be used to produce titanium mill products for aircraft, chemical, petroleum and other industries. □

A linking of mechanical engineering experience in supersonic engine development with chemical engineering experience in the manufacture of special fuels is the basis of a new joint program of applied research in supersonic aircraft and missile propulsion by Marquardt Aircraft Company, Reaction Motors, Inc., and Olin Mathieson Chemical Company. □

Multi-million-dollar expansion program of Cosden Petroleum Corp. will include a new Rexforming unit, a Unifining unit, and modifications on the company's present UOP Platforming unit.

The Rexformer, engineered and designed by Universal Oil Products Co., will be on stream late next spring, will, with the other units, raise the quality of Cosden's gasolines and high purity aromatics. □

Installation of a modern quality control laboratory has been completed at the Chemigum plant of Goodyear's Chemical Division. Renovations include an air filtration system, rebuilt dryer, new electronic metal detector. Under the supervision of a chemical engineer the new lab team is responsible for quality control of all products manufactured in the plant. □

A Recommended Commercial Standard for rigid Polyvinyl Chloride Plastic Sheets is now before the industry for endorsement. Proposed by the Society of the Plastics Industry, and being worked on by the Commodity Standards Division of the Office of Technical Services, it covers physical and chemical properties, and methods of test for high impact and normal impact resistant sheets. If the standard is endorsed by a majority of the industry it will be issued by the Dept. of Commerce as a voluntary standard. □

Free drugs, antibiotics and surgical supplies are being shipped to flood devastated areas by Chas. Pfizer and American Cyanamid.

At the height of the disaster a Pfizer truck went into the flood area with $50,000 supply of antibiotics and other drugs, the company is replacing drugstore stocks damaged by water free of charge. Cyanamid has offered all required drugs the six flood-stricken states might need—all free of charge.

In addition, Pfizer launched a unique campaign to raise much-needed money for the flood victims by offering to give $2 for every $1 contributed by the employees of its Groton, Conn., plant. Response has been remarkable so far. □

Use of X-Ray analysis in industrial installations is growing rapidly. More than 57% of the installations now in use were installed after 1950. □

A leading pipe fabricator, Southwest Fabricating & Welding Co., Inc., Houston, Tex., has been acquired by Walworth Company, a major manufacturer of valves and pipe fittings. Both companies, and the new combined company, serve the chemical, petro-chemical, and oil industries. □

versatile adaptability

. . . for all fine filtering

SPARKLER HORIZONTAL PLATE FILTERS

Versatile adaptability make this filter the logical choice of filtration engineers for difficult filtering problems.

Every filtering job usually presents an individual problem involving a combination of various kinds of screens, papers and filter aid. Frequently temperatures are encountered that call for a brine or steam jacketed tank. Linings; plastic or rubber may be needed, with tank and plate metals to fit the product such as mild steel, monel, nickel, stainless steel, bronze or Hastelloy. Constructed to meet ASME specifications when required.

All these structural and material combinations are easily achieved with the Sparkler Horizontal Plate filter.

No fibrous adhesive material is ever required to hold the filter cake on the horizontal plate. The cake is firmly supported on the plate with no danger of cracking or slipping even with a variation in pressure or a complete shutdown in the filtering operation. The patented Sparkler scavenger plate filters almost the last drop in a batch, and allows practically a complete recovery of the product.

Constant filtering quality is maintained from start to the end of the cycle, no break through can occur in a Sparkler Horizontal Plate filter.

What other filter can match this versatility and positive performance under a wide variation of filtering conditions?

Place your filtering problem in the hands of our filtration engineers. They have developed many successful methods of filtering difficult materials and may be able to prescribe a solution to your problem without wasteful experimentation.

Write Eric Anderson for personal attention

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Filtration engineering and manufacturing has been our exclusive business for over 30 years.

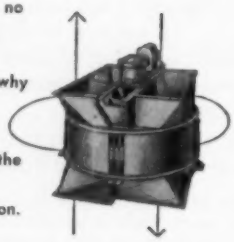
reduce slag

stay on stream at top capacity months longer with the Ljungstrom® Air Preheater

HOW FAST IS "WRITE OFF"?

By cutting turnaround time alone, the Ljungstrom means major savings for you. When you take the other Ljungstrom advantages into account—up to 20% fuel saving . . . more economical furnace design, with no need for convection surfaces . . . burns many fuels you used to throw away . . . consistently higher through-put . . . higher product quality—you can see why a Ljungstrom is paid out in just a few months.

For more complete details on what the Ljungstrom Air Preheater can do for you . . . for an analysis of the heat recovery benefits attainable in fuel burning equipment—call or write The Air Preheater Corporation.



Wherever You Burn Fuel, You Need Ljungstrom

The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves, the heat is transferred from the waste gases to the incoming cold air.

Slag—primary cause of reduced capacity—can be substantially reduced by the Ljungstrom Air Preheater.

That's because preheated air mixes more thoroughly with fuel. The result is better combustion . . . and less slag-forming material present in the furnace. Oil tubes stay cleaner . . . stills stay on stream at top capacity for months longer. As an example, one pipe still in an eastern refinery dropped from 16,000 barrels a day to 12,000 because of slag. Now, with a Ljungstrom and modern high-temperature burners, the still operates continuously at 18,000/20,000 barrels.

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CLEVELAND and the ATOM

EJC NUCLEAR CONGRESS
A.I.Ch.E. ATOMIC EXPOSITION

From the nuclear weapons and power programs, developments emerge almost daily. Now, two great coming events at Cleveland—the concurrent Congress and Exposition—are ready to bring chemical engineers up-to-date. At the Congress, the papers represent an evolvement from Geneva, written and de-classified just for Cleveland. Here is the chance to listen, meet, and exchange views with men from other disciplines bonded together by mutual nuclear interest. At the Exposition, emphasis moves to the practical, demonstrations and displays of what has already been done, of the tools needed for intense radiation, high temperatures, and other special conditions. All in all, this will be the greatest opportunity for the chemical engineer to get the broad picture, and fill in all the details necessary for his firm's future nuclear role.

EJC NUCLEAR CONGRESS PROGRAM ANNOUNCED

Compiled by D. J. Lynds

MONDAY, DECEMBER 12

SAFETY AND SITE SELECTION FOR REACTORS

1. Interpretation of the Purpose, Scope, and Operation of the Reactor Safeguard Committee, C. Rogers McCullough, A.E.C. Reactor Safeguard Committee (ASME)

2. Reactor Site Selection, C. H. Topping, Du Pont (AIChE)

3. Waste Disposal as Related to Site Selection, Arthur E. Gorman, A.E.C. (ASCE)

6. Meteorology as Related to Reactor Site Selection, Fred D. White and Donald H. Pack, U. S. Weather Bureau (ASCE)

9. Suggested Specifications for Design and Operation of Research Reactors, Richard H. Graham, A.E.C. (ASCE)

REACTOR TECHNOLOGY

39. Liquid Metal Fuel Reactor for Central-station Power, Donald J. Sengstaken (Long Island Lighting Co.) and Edwin Durham (Babcock and Wilcox) working at Brookhaven (ASME)

299. Materials Testing Reactor Operational Behavior, John R. Huffman, Phillips Petroleum (AIChE)

280. Engineering Design of EBR-II, L. J. Koch, Argonne (AIChE)

34. Internally Cooled Liquid Metal Fuel Reactor, R. J. Teitel, Brookhaven (ANS)

35. Two-fluid Breeder Reactor Concept, L. I. Katzin and B. I. Spinrad, Argonne (ANS)

30. Army Packaged Power Reactor, Kenneth Kasschow, American Locomotive Co.

REVIEWS OF LITERATURE IN ATOMIC ENERGY FIELDS

239. Nuclear Engineering Literature, Raymond L. Murray, No. Carolina State College (ACS)

238. Literature on Nuclear Power Reactor Technology, Virginia Sternberg, Westinghouse (ACS)

302. Radiation Hazards and Protective Measures: Pertinent Literature, John P. Binnington, Brookhaven (ACS)

303. Compilation of Nuclear Data, Katharine Way, National Research Council (ACS)

REACTOR TECHNOLOGY—HEAT TRANSFER

43. Calculation of the Distribution of Heat Liberation Rates in Nuclear Reactor Components, Lloyd G. Alexander, Oak Ridge (AIChE)

Steady State and Transient Heat Transfer Problems in Water-cooled Reactors, L. S. Mins, Westinghouse (ASME)

46. Steam Generation in a Reactor, M. W. Carbon, W. D. Gilbert, C. R. McNutt, and R. Neidner, General Electric (ASME)

47. Heat Transfer to Water Flowing Parallel to a Rod Bundle, Philip Miller, James J. Byrnes, and David M. Benforado, Walter Kidde Nuclear Labs. (ANS)

HEAT TRANSFER AND FLUID FLOW

Free Connection Heat Transfer Rates Inside a Horizontal Pipe, J. P. Fraser and D. J. Oakley, General Electric (ASME)

56. Hydraulic Analysis of Sudden Flow Changes in a Complex Pumping Circuit, G. E. Alves, DuPont (AIChE)

58. Design of Heat-exchanger Heads for Low Holdup, M. J. Cichelli and D. F. Boucher, DuPont (AIChE)

59. Oscillatory Behavior of a Two-phase Natural Circulation Loop, Eugene H. Wissler, H. S. Isbin, and N. R. Amundson, U. of Minnesota (AIChE)

349. Flow Distribution Among Parallel Heated Channels, Alan R. Gruber and Seymour C. Hyman, Nuclear Development Corp. of Amer. (AIChE)

RADIATION DAMAGE TO STRUCTURAL MATERIALS

89. Effects of Nuclear Reactor Radiations on Structural Materials, Ira F. Zartman, A.E.C. (ASCE)

Radiation Damage to Structural Materials, Bruch, McHugh, and Hockenbury, Knolls Laboratory, General Electric (AIME)

(Continued on page 70)

ATOMIC EXPOSITION TO FEATURE

Compiled by D. J. Lynds and C. H. Talbott

For additional information, bulletins, etc. on Exposition exhibits circle numbers on Data post card, p. 87.

DS 200—Airmec, Ltd., Bucks, Eng.—Booth 228.

DS 206—Associated Valve & Engineering Co., Washington, D. C.—Booth 975

DS 211—Baldwin Instruments Co., Kent, Eng.—Booth 228.

DS 215—British Board of Trade, Detroit.—Booth 228.

DS 220—Catalytic Construction Co., Phila.—Booth 420.

DS 231—Dynatron Radio Ltd., Berks, Eng.—Booth 228.

DS 236—Ericsson Telephones Ltd., Notts, Eng.—Booth 228.

DS 240—The Gaertner Scientific Corp., Chicago.

DS 246—Instruments Publishing Co., Pitts.—Booth 426.
Periodicals and books

DS 247—Isotope Developments Ltd., Reading, Eng.—Booth 228.

DS 252—P. M. Lennard Co., Inc., Jersey City, N. J.—Booth 212.

DS 303—Aircraft Porous Media, Inc., Glen Cove, N. Y.—Booth 619.
Porous metals and filtration equipment.

DS 201—Ajusto Equipment Co., Toledo, O.—Booth 219.
Laboratory furniture.
Bulletins: Chairs; stools; price list.
Rex Dawson, pres.; S. W. Heer, serv. mgr.

(Continued on page 70)

EJC NUCLEAR CONGRESS

Effect of Nuclear Radiation on Structural Materials, Wilson and Billington, Oak Ridge (AIME)

92. Diffusion of Fission Gases in Metallic Uranium, M. B. Reynolds, General Electric (AIME)

93. Some Effects Produced in Graphite by Neutron Irradiation in the BNL Reactor, W. L. Kosiba, G. J. Dienes, and D. H. Gurinsky, Brookhaven (AIME)

94. Irradiation Effects in Uranium and Its Alloys, S. H. Paine and J. H. Kittel, Argonne (ANS)

REACTOR TECHNOLOGY—METALLURGY AND ALLOYS

101. Uranium Zirconium System, A. N. Holden and W. E. Seymour, Knolls Laboratory, General Electric (AIME)

102. Effects of Some Impurities on Mechanical Properties of Thorium Metal, D. T. Peterson, R. F. Russi, and R. L. Mickelson, Iowa State Col. (AIME)

103. Strengthening of Thorium by Alloying, Heat-treatment, and Cold-work, H. R. Ogden, R. M. Goldhoff, and R. I. Jaffee, Battelle (AIME)

104. Properties of Zircaloy-2, D. E. Thomas and F. Forscher, Westinghouse (AIME)

352. Review of Solid Hydrides, H. McCullough and B. Kopelman, Sylvania Electric Corp. (AIME)

RESEARCH REACTORS AND RADIATION LABORATORIES

Dynamic Characteristics of Light- and Heavy-water Research Reactors, Manson Benedict et al., M.I.T. (AIChE)

155. Ford Nuclear Reactor and Phoenix Memorial Laboratory, Russell B. Mesler, William K. Luckow, and Henry J. Gomberg, U. of Michigan (AIChE)

357. Control System for Research-type Nuclear Reactors, E. T. Davis, V. S. Underkoffler, and R. N. Brey, Leeds and Northrup (AIEE)

156. Ventilating Radiological Laboratories, M. G. Kershaw, DuPont (AIChE)

159. "Containment" Philosophy at the Savannah River Laboratory, A. J. Hill, Jr., DuPont (AIChE)

RADIOISOTOPES AND TRACER TECHNIQUES

160. Use of Radioisotopes in Materials Testing, John L. Kuranz, Nuclear Instrument and Chemical Corp. (ASTM)

161. Application of Radioactive Tracers to Engine Research, A. Hundere, G. C. Lawrason, and J. P. O'Meara, Southwest Research Institute (SAE)

162. Radioactive Method for Measuring Engine Deposits, J. G. Mingle, H. W. Sigworth, and B. A. Fries, California Research Corp. (SAE)

163. Electrical Contact Studies with Radioactive Tracers, C. R. Lewis, Chrysler Corp. (SAE)

165. Tracer Techniques Applied to Sulfur Vulcanization—Reversion in Mercaptobenzothiazole Vulcanization, Irving Auerbach, Goodyear Tire and Rubber (ACS)

165a. Use of Self-luminous Materials Employing Radioisotopes, C. W. Wallhausen, U. S. Radium Corp. (ASTM)

REVIEWS OF LITERATURE IN ATOMIC ENERGY FIELDS

276. Problems in Nuclear Terminology, R. T. Overmon and D. R. Smith, Oak Ridge (ACS)

Organization of an Atomic Energy Information Service, Hoyland D. Young, Argonne (ACS)

236. Literature of Instrumentation for Radiological Studies, Marjorie Comstock, Brookhaven (ACS)

237. Literature on Biological Effects of Ionizing Radiations, M. Ingram and W. B. Mason, U. of Rochester (ACS)

240. Applications of Radioisotopes in Chemical Studies, J. W. Borland, Allied Chemical and Dye (ACS)

TUESDAY, DECEMBER 13

SAFETY SHIELDING AND REMOTE CONTROL I

7. Essential Differences Among Basic Types of Reactors and Comparison of Significant Safety Considerations Peculiar to Each, Stuart McLain and Raymond O. Brittan, Argonne (ASME)

8. Proposed Structural Design Basis for Nuclear Reactor Pressure Vessels, W. E. Cooper, Knolls Laboratory, General Electric (ASME)

Safety Aspects of the Fast Breeder Reactor, W. J. McCarthy and F. C. McMath, Atomic Power Div. Assoc., Inc. (ASME)

Safety Aspects of Water-cooled and -Moderated Reactors, R. J. Creegan, Westinghouse (ASME)

11. Reactor Shielding, E. P. Blizard, Oak Ridge (ASME)

SAFETY SHIELDING AND REMOTE CONTROL II

Experimental Facilities for Shielding Studies, H. E. Hungerford, Jr., Atomic Power Development Assoc. (ASME)

17a. Radiation Hazard Control for a Power

A.I.Ch.E. ATOMIC EXPOSITION

DS 202—Alco Products, Inc., Schenectady, N. Y. —Booth 307.
Packaged power reactor model; heat exchangers; steam generators; prefabricated pipe; nuclear power engineering services.
Bulletins: Nuclear power; Alco Economy; feedwater heaters; evaporators; finned exchangers; flanges and welding fittings. Alcoplate.
K. Kasschau, mgr. engrg.-atomic energy; R. T. Sawyer, dir. research; P. N. Strobell, product mgr. M. D. Raymond & R. H. Binkerd.

DS 203—Allis-Chalmers Mfg. Co., Milwaukee, Wisc.—Booth 303.
Argonne power plant model hermetically sealed pump; electric motors & controls; pumps.
Bulletins: All products.
J. Bronaugh; W. F. Bueche, R. M. Friddle, J. T. Petersen, L. E. Stacy, W. Urmetz

DS 304—American Machine & Foundry Corp., New York—Booth 227.
AMF Reactor Models, operating control mechanisms, manipulators.

DS 204—American Turbine Corp., New York—Booth 428.
Layout of 60 MW closed cycle gas turbine nuclear power plant with actual compressor-turbine rotor from 2 MW plant for Escher Wyss Ltd., Switzerland. Sample of extended heat transfer surface used in plant, and gas lubricated bearing.
Bulletins: Closed cycle gas turbine power plant.
P. B. Taylor, R. F. Benenati; G. H. Kurz; S. T. Robinson

DS 205—Anton Electronic Labs, New York—Booth 418.
Reactor control and monitoring systems, nuclear tubes and instruments.
Bulletins: Exhibit.
H. Kalisman; Hal March; N. G. Anton, pres. & dir.

DS 206—Assembly Products, Inc., Chesterland, O.—Booth 423.
Panel meters, pyrometers, and meter-relays.
Bulletins: Meter-Relays; Simplytrols; Versatrols; Meters; Pyrometers.
J. Saint-Amour; R. H. Pugsley, L. Glauberman, P. Saint-Amour, B. Thompson

DS 305—Atomic Development Mutual Fund, Washington—Booth 820.
Atomic industry map denoting kinds of atomic activity.

DS 306—Atomic Energy for Industry, Inc., Cleveland—Booth 126

DS 208—Automatic Coil Winder & Electrical Equip. Co., Ltd., New York—Booth 228.
Radiac survey, portable D. C. amplifier, vacuum tube voltmeter.

DS 307—Avco Mfg. Co., Stratford, Conn.—Booth 304.

DS 209—Babcock & Wilcox Co., New York—Booth 431.
Large power reactor model. Complete planning design, development, fabrication, and construction services for many types of nuclear steam generators and research reactors.
Bulletins: Reactors for Power Plant; Consolidated Edison Nuclar Generating Station; Research Reactors.
W. C. Gumprich; M. A. Cordovi; R. T. Schomer; J. W. Landis; D. K. Davies

DS 210—Bailey Meter Co., Cleveland, O.—Booth 417.
Receiver recorder controller; stainless flow meter; high speed temp. sensing element; control room models and diagrams.
Bulletin: Controls for Power Reactors.
P. S. Dickey; C. H. Barnard; F. H. Fellows; F. J. Ghezzi; P. R. Meyers

DS 212—Bendix Aviation Corp., Research Labs Detroit, Mich.—Booth 605
Research reactor model; research reactor core model; reactor simulator; reactor control equipment.
Bulletin: Reactor design.
A. C. Hall; J. LaRue; F. Larin; A. C. Prine

DS 213—Bendix Aviation Corp., Cincinnati Div., Cinn. O.—Booth 605
Radiation gauge for controlling specific gravity, density, liquid level etc.; nuclear dosimeters for personnel protection.
Bulletins available.
L. E. Rassmussen; R. K. Stoms; G. J. Roseblit

DS 214—Bendix Aviation Corp., Pioneer Central Div., Davenport, Iowa—Booth 605.
Ultrasonic cleaning system with 2KW generator, magnetostrictive transducer.

Reactor, G. Hoyt Whipple, U. of Rochester (ASME)

348. Ventilation Problems and Their Solutions at Feed-materials Production Center, Walter Shurkin, National Lead (AIChE)

309. Idaho Chemical-processing-plant Remote Analytical Facility, F. W. Dykes, R. D. Fletcher, E. H. Turk, J. E. Rein, and R. C. Shank, Phillips Petroleum (ACS)

REACTOR TECHNOLOGY—LIQUID METALS

Extracting Heat from Liquid Metal Fuels, R. T. Schoemer and J. A. Klapper, Babcock and Wilcox (ASME)

49. Selection of Materials, Design, and Specialized Fabrication Procedures for Sodium- and Sodium Potassium-cooled Heat Transfer Systems, W. L. Fleischmann and R. F. Koenig, Knolls Laboratory, General Electric (ASME)

50. Liquid Bismuth as a Fuel Solvent and Heat Transport Medium for Nuclear Reactors, O. E. Dwyer, D. H. Gurinsky, and J. R. Weeks, Brookhaven (ASME)

52. Specific Heats of Liquid Metals and Liquid Salts, Thomas B. Douglas, Bureau of Standards (ASME)

66. Purity Control in Sodium-cooled Reactor Systems, Warren H. Bruggeman, Knolls Laboratory, General Electric (AIChE)

67. Sampling and Analysis for Impurities in Liquid Sodium Systems, J. R. Humphreys, Jr., Argonne (AIChE)

70. Use of Zirconium in Liquid Sodium Systems, F. E. Bowman and D. D. Cubicciotti, North American Aviation, Inc. (AIChE)

71. UO_2-NaK Slurry as a Possible Reactor Fuel, B. M. Abraham and H. E. Flotoro, Argonne (ANS)

REACTOR MATERIALS

Fuel-element Economics in Sodium-graphite Power Reactors, Woolsey and Hayward, North American Aviation, Inc. (AIME)

108. Oxidation Behavior of Reactor Materials, Hudde, Atomic Energy Research Establishment, Harwell, England (AIME)

109. Metallurgical Aspects of Corrosion Resistance of Zirconium, D. S. Kneppel, Nuclear Metals, Inc. (AIME)

110. Ceramic Fuel Materials for Nuclear Reactors, J. R. Johnson, Oak Ridge (AIME)

112. Boron Compounds for Nuclear Applications, Gordon R. Finlay, Norton Co. (ACS)

319. Evlution of Gas from Graphite Moderator Material, R. L. Carter and W. J. Greening, North American Aviation, Inc. (ANS)

REACTOR MATERIALS AND DESIGN

113. Production of Uraium Metal, D. S. Arnold, C. E. Polson, and E. S. Noe, National Lead (AIME)

115. Mechanical Properties of Uranium-molybdenum Alloys, M. B. Waldron, R. C. Burnett, and S. F. Pugh, Atomic Energy Research Establishment, Harwell, England AIME)

Fuel-element Design, C. E. Weber, General Electric (AIME)

124. Powder Metallurgy of Uranium, H. H. Hausner and J. L. Zambrow, Sylvania Electric Products, Inc. (AIME)

333. Hydrogen - uranium Phase Diagrams, M. W. Mallett and M. J. Trzeciak, Battelle (ASM)

334. Review and Redetermination of Hydrogen-uranium Relationships, M. W. Mallett, M. J. Tzreciak, and C. B. Griffith, Battelle (ASM)

ANALYTICAL METHODS AND FACILITIES

17. Design of Radiation Analytical Facilities at Oak Ridge National Laboratory, H. E. Goeller and E. J. Frederick, Oak Ridge (ANS)

158. Sampling Devices for High-level Radiochemical Plants, J. W. Landry, Oak Ridge (ACS)

308. Neutrons in Chemical Analysis, W. A. Brooksbank, Jr., G. W. Leddicotte, and J. E. Strain, Oak Ridge (ACS)

315. Gamma Spectrometric Analysis in Reactor Technology, W. S. Lyon, Jr., W. A. Brooksbank, Jr., S. A. Reynolds, and G. W. Leddicotte, Oak Ridge (ACS)

CATALYSIS AND CHEMICAL REACTIONS

137. Effect of Gamma Radiation on Aqueous Ethylene-oxygen Solutions, Ernest J. Henley, Jane P. Schwartz, and Wesley P. Schiffries, Columbia U. (AIChE)

138. Rates of Chlorination of Aromatic Hydrocarbons in the Presence of Gamma Radiation, David E. Harmer, Joseph J. Martin, and Leigh C. Anderson, U. of Michigan (AIChE)

139. Electrolytic Separation of Metallic Isotopes, James H. Andrews, Ivan Ceresna, F. A. Rohrman, and William Utlaut, U. of Colorado (AIChE)

350. Use of Nuclear Radiation in Combustion Research, Martin E. Gluckstein, Richard B. Morrison, and John V. Nehemias, U. of Michigan (ARS)

RADIATION EFFECTS ON POLYMERIZATION AND CHEMICAL REACTIONS

241. Some Aspects of Radiation—Induced Cross Linking and Degradation, A. R. Schultz, Minnesota Mining and Mfg. Co. (ACS)

141. Isotope Effects in the Gamma-ray-induced Reaction of Hydrogen and Hydrogen Peroxide in Aqueous Solutions, Sheffeld Gordon, W. R. McDonald, and E. J. Hart, Argonne (ACS)

243. Literature Resources on the Radiation Effects of High Polymers, F. A. Pecjak and K. H. Sun, Westinghouse (ACS)

244. Radiation Stability of Chromium VI Ions in Acetate Buffered Solutions, R. L. Andelin and E. L. Anderson, Phillips Petroleum (ACS)

REACTOR TECHNOLOGY

264. Determination of Neutron Intensity and Gamma Spectrum of Neutron Sources, L. B. Gnagey, Mound Laboratory (IRE)

Two Beryllium-moderated Critical Assemblies, E. L. Zimmerman and Dixon Callihan, Oak Ridge (ANS)

266. Measurement of the Conversion Ratio for a Fast Breeder Reactor, Walter Y. Kato, Frederick S. Kirn, and W. Charles Redman, Argonne (ANS)

267. Recent Results of Computation of Fission-product Levels in Reactor Fuels, J. O. Blomeke, Oak Ridge (ANS)

268. Temperature-dependent Kinetics of Cir-

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Bulletins: Exhibit; data on ultrasonic cleaning.
T. J. Bulat; R. W. Hancock; G. Brown; R. Lowry; P. Gardner

DS 308—S. Blickman, Inc., Weehawken, N. J.—Booth 312.

DS 216—Brush Beryllium Co., Cleveland, O.—Booth 617.
Beryllium metal and oxide for nuclear purposes; samples of beryllium products displayed.
Bulletins: Beryllium products and properties.
N. W. Bass, v.p.; B. Sparks, asst. sales mgr.; L Fowles, field rep.; W. W. Beaver, dir. res. & dev.

DS 309—Buckeye Bobbin Co., Cleveland—Booth 422.

DS 217—Burndept Ltd., Kent, England—Booth 228.
Scintillation counter; ratemeters; radiation monitors.

DS 218—Byron Jackson Co., Los Angeles.—Booth 615.
"Canned" pumps for nuclear applications; mechanical seal for both nuclear and conventional pumping equip.; Vibrotron; digital pressure gage for reactor control.
Bulletins: Pumps and auxiliaries for Atomic Power Plants, Mechanical Seals, electronic instruments.

DS 219—Callery Chemical Co., Callery, Pa.—Booth 311.
Electromagnetic pumps; magnetic flowmeters; high-temp. pressure transmitters; NaK alloys as heat transfer agents.
Bulletins: On items displayed.
C. H. Staub; D. J. Wain

DS 221—Central Research Labs, Inc. Red Wing, Minn.—Booth 440.
Master-slave remote manipulators.
Bulletins: Complete line of manipulators and accessories.
F. G. Chesley; D. G. Jelatis; G. M. Lee

DS 222—Chemical Rubber Co., Cleveland, O.—Booth 120.
Laboratory furniture & equipment; "Handbook of Chemistry and Physics."
Bulletins: Flexiplan Furniture; Labwasher; others.
B. J. Starkoff, v.p.; L. Muslay, sales mgr.; C. Schroeder, product mgr.; F. Hays; L. Mountford.

DS 310—Chemiquip Co., New York—Booth 436.

DS 223—Chem Ray, Inc., Cleveland, O.—Booth 429.
Research and engineering for industry and govt.
Bulletins: 8 p. on General activities.
C. F. Robards; D. Steigerwald; E. Haylett

DS 224—Cleveland Electric Illuminating Co., Cleveland O.—Booth 129.
Area development display material—motion picture "Land of Promise."
Bulletins: Data on displayed material and markets.
R. L. Dechant; R. M. Atkins, W. H. Lamprecht

DS 311—Combustion Engineering Co., New York—Booth 101

DS 225—Cooke, Troughton & Simms, Ltd.; (U. S. Agent, Malden, Mass.)—Booth 228.
Nuclear research microscope.

DS 312—Consolidated Siphon Supply Co., New York.—Booth 412.

DS 226—Crane Co., Chicago, Ill.—Booth 128.
Specialized flow control valves; titanium pipe.
Bulletins: Packless diaphragm valves, corrosion-resistant alloy valves.
J. Bradbury; F. Schairer; R. Wetzel; E. Oates; R. Strausser

DS 227—Crawford Fitting Co., Cleveland, O.—Booth 419.
Swagelok tube fittings.
F. A. Lennon, pres.; A. P. Lennon, treas.; E. E. Alto, gen. mgr.; D. P. Haag, sales mgr.

DS 313—Crucible Steel Co. of America, Pitts., Pa.—Booth 331.

DS 228—Cuno Engineering Corp., Meriden, Conn.—Booth 123.
Poro-Klean porous stainless steel filter for high temp., high press., and corrosive applications.
E. D. Kane, dir. dev.; V. L. Towner, E. C. Swift (V. L. Towner Co.)

DS 229—Curtiss-Wright Corp., Electronics Div., Carlstadt, N. J.—Booth 139.
Gamma and beta radiation detectors and in-

EJC NUCLEAR CONGRESS *(continued)*

culating Fuel Reactors, J. A. Fleck, Jr., Brookhaven (ANS)

268a. Subcritical Pile for Rapid Reactivity Measurements, R. G. Axtmann, G. Dessauer, and T. F. Parkinson, DuPont (AIChE)

WEDNESDAY, DECEMBER 14

INSTRUMENTATION FOR REACTORS

18. Hanford Reactor Instrumentation, E. See Day, Jr., General Electric (AIEE)

20. Reactor Instrumentation at Chalk River, Albert Pearson, Atomic Energy of Canada, Ltd. (AIEE)

21. Recent Development in Instrumentation for Reactor Measurements at Argonne National Laboratory, H. Bryant, R. Carlson, C. Curtis, and S. G. Kaufman, Argonne (ANS)

22. Problems of Production Reactor Instrumentation, T. R. VickRoy, DuPont (AIChE)

19. Dual-function System for Gamma Radiation Measurement, M. B. Leboeuf, R. E. Connally and L. F. Miller, General Electric (AIEE)

REACTOR CONTROL AND INSTRUMENTATION

24. Instrumentation Requirements for a Research Reactor Facility, Clifford K. Beck, No. Carolina State Col. (ASME)

25. Reactor Controls and Instrumentation, Samuel Untermyer, General Electric (ASME)

26. Dynamics and Control of Nuclear Power Plants, A. B. Van Rennes, J. C. Simons, Jr., and T. S. Gray, M.I.T. (AIEE)

27. Hydraulic Systems in Reactor Control, Michael Silverberg, Ford Instrument Co. (ASME)

28. Control of Heavy-water-moderated Massive Fuel Reactors, E. Siddall, Atomic Energy of Canada, Ltd. (AIEE)

353. Power and Temperature Control of Pressure, Hamilton, et. al. (AIEE)

REACTOR AND COOLANT TECHNOLOGY

62. Water Technology for Primary Systems in Water-cooled Power Reactors, J. M. Seamon, Westinghouse (AIChE)

63. Survey of Homogeneous-reactor Chemical Problems, C. H. Secoy, Oak Ridge (ACS)

64. Measurement of Reactor-core Temperatures, S. S. Jones, General Electric (AIChE)

65. SIR Primary Coolant System, J. P. Verkamp, General Electric (AIChE)

57. Effects of Coolant-flow Orificing and Monitoring on Safe Pile Power, Michael Markels, Jr., Columbia U. (AIChE)

REACTOR TECHNOLOGY—CORROSION

74. Comparison of Sodium, Lithium, and Lead as Heat Transfer Media from a Corrosion Standpoint, W. D. Manly, Oak Ridge (ASME)

75. Mass Transfer of High-temperature Alloys in Lead, J. V. Cathcart and W. D. Manly, Oak Ridge (AIME)

76. Apparatus for Visual Study of Corrosion by Hot Water, Daniel R. Grieser and Eugene M. Simons, Battelle (AIChE)

77. Sodium Hydroxide Pump Loops, N. E. Miller and E. M. Simons, Battelle (AIChE)

REACTOR TECHNOLOGY—DESIGN AND CONSTRUCTION

78. Fuel Elements for Nuclear Reactors, John B. Anderson, Combustion Engineering, Inc. (ASME)

79. Design and Development of Components for SRE, William E. Parkins, North American Aviation (ASME)

81. Power-conversion Systems for Dual-cycle Boiling Reactors, V. A. Elliott and T. Trocki, General Electric (ASME)

82. Design and Operation of Freeze Seal Valve and Pumps, R. Cygan and A. M. Stelle, North American Aviation (AIChE)

323. High-pressure Diaphragm Pumps for Reactors, J. S. Culver and C. B. Graham, Oak Ridge (ANS)

MATERIALS AND METALLURGY

125. Diffusion of Uranium Through Graphite, L. D. Loch and J. R. Gambino, Battelle (AIChE)

126. Preparation of Dense Beryllium Oxide, C. Hyde, J. F. Quirk, and W. H. Duckworth, Battelle (AIChE)

128. Enameling of Zirconium, J. Schultz, H. P. Tripp, B. W. King, and W. H. Duckworth, Battelle (AIChE)

129. Low Manganese Carbon Steel for Nuclear Applications, H. F. Beeghly, Jones and Laughlin Steel Corp. (AIME)

130. Nondestructive Testing of Reactor Fuel Elements, W. J. McGonnagle, Argonne (ANS)

LEGAL AND INSURANCE PROBLEMS

207. AEC Licensing Policies and Procedures (AIF)

208. The Insurance Problem (AIF)

209. State and Federal Regulations (AIF)

210. Declassification and Dissemination of Information (AIF)

211. Patent Problems (AIF)

Catalogue of Unique Legal Problems in Atomic Energy, E. B. Stason, U. of Michigan (ACS)

EDUCATIONAL REQUIEMENTS FOR NUCLEAR ENGINEERING

(Panel discussion led by C. K. Beck and C. F. Bonilla)

Nuclear and Thermal Design of Power Reactors, John R. Menke, Nuclear Development Assoc. (ASEE)

Mechanical Design of Power Reactors, Robert Fritz, Knolls Laboratory, General Electric (ASEE)

Fuel-element Metallurgy, Corrosion, and Coolant Problems, Stuart McLain and Frank G. Foote, Argonne (ASEE)

Reactor Control and Instrumentation, M. A. Schulz, Westinghouse (ASEE)

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A.I.Ch.E. ATOMIC EXPOSITION *(continued)*

tensity meters.
Bulletins: On products displayed.
C. O. Cary, sales mgr.; R. E. Jacobson, mgr., component & instru. sales; J. F. Orr, indus. controls sales mgr.

DS 314—Daystrom Instrument, Archbald, Pa.—Booth 328.

DS 230—Detectolab, Inc., Chicago.—Booth 202.
20 channel differential pulse height analyzer; single channel analyzer; linear amplifiers; coincidence circuit; gamma spectrometers; high voltage supplies, scaling circuits; scintillation probes; counting rate meter circuits.
K. H. Johnson, v.p.; H. M. Griffin

DS 232—Edwards High Vacuum, Ltd.—Booth 228.
Pumps and gauges; static vacuum components.

DS 233—Ekco Electronics, Ltd. (U. S. Agent, Amer. Trader Corp. N. Y.).—Booth 228.
Automatic scaler plus liquid scintillation counter; neutron monitor; nucleonic thickness gauge.

DS 234—Electronic Instruments, Ltd. (U. S. Agent, R. J. Bailey N. Y.).—Booth 228.
Vibron electrometer; nucleonic weight controller.

DS 235—E. M. I. Research Labs (English).—Booth 228.
Multiplier photo-tubes.

DS 237—Falk & Co. (U. S. Agent, Rice-Peterson Sales Inc., Palo Alto, Calif.).—Booth 228.
Remote handling tool with swivel head.

DS 316—H. K. Ferguson Co., Cleveland, O.—Booth 407.

DS 317—Finnell System, Inc., Elkhart, Ind.—Booth 203.

DS 238—Flanders Mills, Inc., Riverhead, N. Y.—Booth 108.
Air supply purification unit.
A. R. Allan, Jr., pres.

DS 239—Fleming Radio. (U. S. Agent, J. Biddle Co., Phila., Pa.).—Booth 228.
Radioactive dust sampling equip.; logarithmic ratemeter; pulse generator.

DS 318—Foster Wheeler Corp., New York—Booth 104

DS 241—Gamma Rays, Ltd. (U. S. Agent, Rice-Peterson Sales, Inc., Palo Alto, Calif.).—Booth 228.
Radiation source materials (4-curies cobalt 60); portable radiographic equipment for pipe line measurement.

DS 242—General Chemical Div., Allied Chem. & Dye Corp., New York.—Booth 208.
Industrial, laboratory and special custom-made chemicals for use in nuclear energy program.
Bulletins: Chemicals, radioisotopes.
C. P. Berdell, mgr. sales; G. T. Stribling, asst. mgr. sales; A. H. Patton, mgr. prod. dev.; K. R. Osborn, mgr. indus. dev.

DS 319—General Dynamics Corp., New York—Booth 301

DS 243—General Electric Co.—Apparatus Sales Div., Schenectady, N. Y.—Booth 515.
Atomic power plant model; research reactor model; atomic power equip. components; nuclear radiation instruments.
Bulletins: Components & Services for Reactor Systems; Putting Atom to Work; Race for Atomic Power; DualCycle Atomic Shortcut; Reactors for Research; Power Generation from Atomic Energy.

DS 302—General Precision Lab., Inc. (Affil. Griscom-Russell)—Booth 434.
Industrial TV camera and monitor.

DS 244—Griscom-Russell Co., Massillon, O.—Booth 434.
Molten metal steam generator; high pressure feedwater heater; special evaporator.
Bulletins: Hi-temp K-fin and plate fin exchangers.

DS 320—Haveg Corp., Wilm., Del.—Booth 205.

DS 245—High Voltage Engineering Corp., Cambridge, Mass.—Booth 319.
Particle accelerators; their use in radiation sterilization and chemical syntheses activation.
D. R. Dewey, v.p.; F. L. Foster, sales mgr.; G. Molesworth, counselor; R. M. Emanuelson & J. F. Bromberger, sales engrs.

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IT PUMPS...

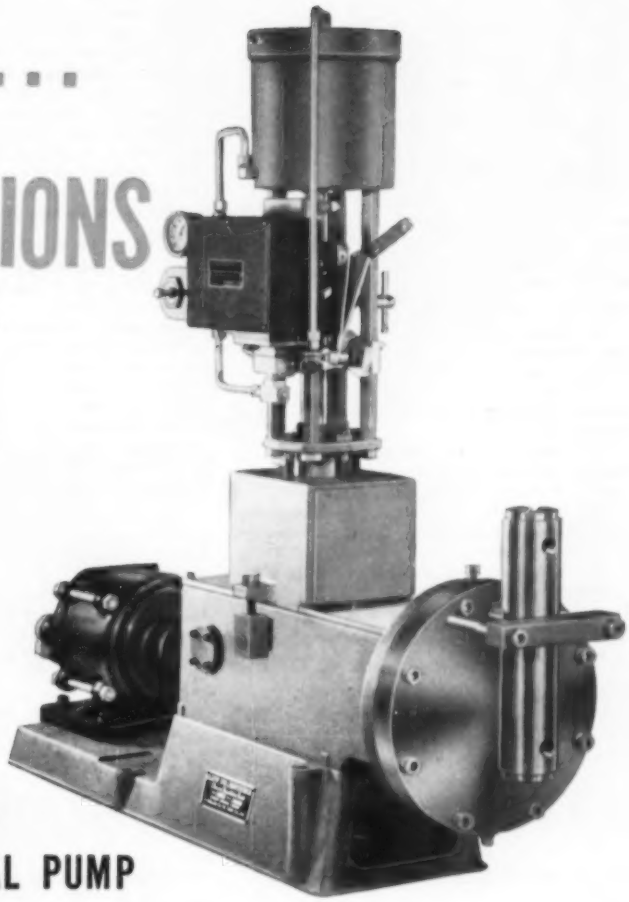
IT METERS...

IT PROPORTIONS

IT FEEDS...

WITHOUT LEAKAGE OR

CONTAMINATION



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EJC NUCLEAR CONGRESS *(continued)*

Design of Radioactivity Facilities and Absorption Shields, John Huffman, Phillips Petroleum (ASEE)

DISSOLUTION AND CHEMICAL PROCESSING

259. Theoretical Approach to Dissolution of Uranium-aluminum Alloys, H. Schneider and C. M . Slansky, Phillips Petroleum (ACS)

260. Chemical Processing of Aqueous Homogeneous Reactor Fuel, D. E. Ferguson, Oak Ridge (ANS)

261. U-Al Alloy Dissolution in Sodium Hydroxide and Mercuric Nitrate-nitric acid Solutions, R. G. Wymer and R. E. Blanco, Oak Ridge (ACS)

278. Volatilization Process for Uranium Recovery, G. I. Cathers and R. E. Leuze, Oak Ridge (ANS)

311. Pyrometallurgical Processing Method for Nuclear Fuels, M. Levenson, Argonne (ASME)

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269. Solvent-extraction Separation of Uranium and Plutonium from Fission Products, J. R. Flanary and F. L. Culler, Oak Ridge (ACS)

270. Extraction of Americium Nitrate with Tributyl Phosphate, Kenneth A. Walsh, Los Alamos (ACS)

271. Extraction of Protactinium from Solid Thorium Fluoride, R. H. Wiswall, Jr., R. J. Heus, and F. T. Miles, Brookhaven (ACS)

273. Utilization of Isotopic Exchange for Radiochemical Separations, D. N. Sunderman and W. W. Meinke, U. of Michigan (ACS)

222. Decomposition of Water by Fission Recoil Particles, J. W. Boyle, W. F. Kieffer, C. J. Hochanadel, T. J. Sworski, and J. A Ghormley, Oak Ridge (ACS)

THURSDAY, DECEMBER 15

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95. Fuel Elements with Nonuniform Fuel Distribution, W. A. Loeb and H. Hausner, Nuclear Development Assoc. (ANS)

96. Fabrication of a Large Zirconium Tank, G. E. Elder and E. C. Miller, Oak Ridge; L. F. Bledsoe and F. V. Daly, Newport News Shipbuilding and Dry Dock Co. (AIME)

98. Equipment and Procedures for Inert Atmosphere Welding of Zirconium and Hafnium, J. S. Theilacker, E. D. Baugh, A. H. Kasberg, and R. B. Stermon; Westinghouse (AIME)

Fabrication and Properties of Thorium, H. A. Saller and J. A. Keller, Battelle (AIME)

356. Methods of Replacing Fuel in Nuclear Reactors, Stuart McLain, Raymond C. Goertz, and Arthur H. Barnes; Argonne (ASME)

ECONOMICS IN REACTOR DESIGN

132. Economic Power Fueling Without U235 Enrichment, W. B. Lewis, Atomic Energy of Canada, Ltd. (AIEE)

134. Special Technical and Economical Aspects of Small Nuclear Power Packages, Tibor F. Nagey, Glen Martin Co. (AIChE)

135. Economics of Radiochemical Plants, W. G. Stockdale, Oak Ridge (ANS)

135a. Economics of a Fast Reactor Reprocessing Cycle, R. W. Kupp, Atomic Power Development Assoc. (AIChE)

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142. Solvent-extraction Separation of U233 and Thorium from Fission Products by Means of Tributyl Phosphate, A. T. Gresky, Oak Ridge (ACS)

143. Fused-salt Processing of Liquid Metal Reactor Fuels, R. G. Bauman, L. Hersch, C. J. Raseman, and J. Weisman, Brookhaven (ACS)

144. Liquid Metal Extraction for Processing of Spent Fuel, A. F. Voigt, Iowa State Col. (AIChE)

145. Pyroprocessing Methods for Nuclear Reactor Fuels, J. R. Foltz, F. Rosen, and W. Gardner, North American Aviation (AIChE)

146. Integrated Miniature Solvent-extraction System for Processing Radioactive Solutions, J. L. Bloom, U. of California Radiation Lab. (AIChE)

148. Conceptual Design and Cost Study for Chemically Processing Irradiated Reactor Fuels, S. M. Stoller, Vitro Corp. (AIChE)

149. Continuous-flow Pilot Plant for Separation of Bromine-fluorine Compounds and Light End-fission-product Fluorides from Uranium Hexafluoride, W. R. Page, C. J. Raseman, E. I. Goodman, and C. H. Scarlett, Brookhaven (AIChE)

150. Flooding Characteristics of a Pulse Extraction Column, G. H. Beyer and R. B. Edwards, Iowa State Col. (AIChE)

151. Process Design for Fission-product Removal from U-Bi Reactor Fuels Using Fused-salt Extraction, O. E. Dwyer, Brookhaven (AIChE)

152. Precipitation Methods for Processing Liquid Metal Fuels and Breeder Systems, R. J. Teitel, Brookhaven (AIChE)

153. Reaction-rate Study of the Dissolution of Low-hafnium Zirconium in Hydrofluoric Acid Solutions, G. R. Hill and Tennyson Smith, U. of Utah (ACS)

DETECTION AND MONITORING OF NUCLEAR DEBRIS IN WATER

178. Instrumentation for Radioactive Pollution Studies—A Survey by AWWA Committee E 5.5, Harold E. Pearson, Metropolitan Water Distr. of So. Calif. (AWWA)

179. Water-quality Problems in Nuclear Energy Development, S. K. Love and W. F. White, U. S. Geological Survey (ACS)

Use of Portable Instruments for Detection and Monitoring of Emergency Levels of Radio-

A.I.Ch.E. ATOMIC EXPOSITION *(continued)*

DS 321—International Nickel Co., New York—Booth 135.

DS 322—Iron Lung Ventilator Co., Cleveland—Booth 901.

DS 323—Jarrell Ash Co., Newtonville, Mass.—Booth 512.

DS 324—Jos., Millen & Miller, Inc., Cleveland.—Booth 124.

DS 301—Kearfott Co., Inc. (Affil. Griscom-Russell)—Booth 434.
Oxide Ceramics.

DS 325—O. G. Kelley & Co., Boston.—Booth 308.

DS 248—Kewaunee Manufacturing Co., Adrian, Mich.—Booth 219.
Airflow Fume Hood and interchangeable gloved boxes; laboratory furniture.
Bulletins: On products displayed.
W. A. Firedrich; J. A. Peay; G. T. Saunders; R. C. Lovell; W. V. Downer; R. L. Mobus

DS 326—Walter Kidde Nuclear Laboratories, Inc., Garden City, N. Y.—Booth 408

DS 249—Kollmorgen Optical Corp., Northampton, Mass.—Booth 201.
Wall-type periscopes; borescopes; inspection scopes.
Bulletin: Industrial Periscopes.
J. L. Maulbetsch, v.p.; J. J. Lerse, dev. engr., J. A. Fetherston, sales mgr.

DS 250—Labgear, Ltd., (U. S. Agent, Pye Corp., N. Y.)—Booth 228.
Pulse amplifier/discriminator; Dekatron counter; Triplegate ratio counter.

DS 327—La Roe Instruments, Inc., Bethesda, Md.—Booth 513.

DS 251—Leeds and Northrup Co., Phila., Pa.—Booth 401.
Atomic reactor control demonstration using Bell & Straus simulator.
Bulletins: Control systems for nuclear reactors; nuclear reactor simulator assembly.
N. Cohn; H. L. Scutt; R. N. Brey; R. K. Davis; J. D. Nelson

DS 253—Lindsay Chemical Co., West Chicago, Ill.—Booth 430.
Thorium, rare earth and Yttrium salts.
Bulletins: Facts booklets.
C. R. Lindsay, III, pres.; M. W. Eichelberger, v.p.; H. E. Kremers, dir., res.; S. B. Treat, sales mgr.; D. Browne, chemist

DS 254—Glenn L. Martin Co., Baltimore, Md.—Booth 129.
Reactors for propulsion and power.
T. F. Nagey; J. A. Hunter; H. F. Dunlap

DS 255—Metals & Controls Corp., Attleboro, Mass.—Booth 317.
Reactor fuel elements and components.
Bulletin: Fuel Element Fabrication.
A. R. Matheson; P. Moffet; H. Wolf; B. Davis; R. Delagi

DS 256—Micro Metallic Corp., Glen Cove, N. Y.—Booth 619.
Porous stainless steel and porous plastic filter media and complete filter assemblies for applications ranging from water to molten metals.
Bulletin: Technical description of products and standard designs.
J. A. Whitwell, sales mgr., C. H. Hacker, sales engr.

DS 328—Mitro-Metric Instrument Co., Cleveland—Booth 107.

DS 239—NRD Instrument Co., Long Island City, N. Y.—Booth 602.

DS 258—Nash & Thompson, Ltd. (English)—Booth 228.
Crystalline and plastic scintillators.
Bulletins and personnel not supplied.

DS 259—National Carbon Co., New York—Booth 220.
Graphite-moderated reactor model and other graphite exhibits.
V. J. Nolan; E. E. Sipp; R. L. Townsend; S. Uhl; N. F. Bowman

DS 330—National Lead Co., New York—Booth 508.

DS 260—National Research Corp., Cambridge, Mass.—Booth 501

activity in Waters, Simon Kinsman, Robert A. Taft Sanitary Engrg. Center (AWWA)

181. Measurement of Radioactivity in Water, L. R. Setter and A. S. Goldin, Robert A. Taft Sanitary Engrg. Center (AWWA)

183. Radiochemical Techniques for Separation of Radioisotopes, Bernd Kahn, Oak Ridge (AWWA)

CHEMISTRY OF SOLUTIONS

218. Solubility of Uranium (IV) Orthophosphates in Perchloric Acid Solutions, James M. Schreyer and L. R. Phillips, Oak Ridge (ACS)

219. Spectrophotometric Investigation of Uranyl Phosphate Complex Formation in Perchloric Acid Solution, C. F. Baes, Jr., Oak Ridge (ACS)

220. Extraction of Iron (III) from Acidic Sulfate Solutions by Di-n-decylamine Sulfate in Benzene, C. F. Baes, Jr., Oak Ridge (ACS)

221. Studies in the Carbonate-uranium System, C. A. Blake, K. B. Brown, D. G. Hill, R. S. Lowrie, and J. M. Schmitt, Oak Ridge (ACS)

223. Recent Developments in High-Temperature E. M. F. Measurements, M. H. Lietzke, Oak Ridge (ACS)

224. Reduction of Uranium (VI) by Iron (II) in Phosphoric Acid Solution, C. F. Baes, Jr., Oak Ridge (ACS)

RECOVERY OF FISSION PRODUCTS

225. Process for Recovery of Large Quantities of Cesium 137 from Fission-product Wastes, W. H. Burgus and H. W. Miller, Phillips Petroleum (ACS)

226. Hot Laboratory Preparations at Kilocurie Level, G. W. Parker, W. J. Martin, G. E. Creek, and P. M. Lantz, Oak Ridge (ACS)

228. Laboratory Development of a Process for Preparation of Kilocurie Quantities of Ba^{140}-La^{140}, Edward L. Anderson, Jr., and C. M. Slansky, Phillips Petroleum (ACS)

230. Continuous Processing of Heterogeneous Reactors, H. H. Hyman and J. J. Katz, Argonne (AIChE)

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Examples of titanium casting process; high vacuum equip.; projected slides.
Bulletins: Research Div. brochure; others.
F. H. Greene, Jr., admin., Nuc. Energy Dept.; F. Maslan, Process Engrg. Dept.; M. Harris, Dev. Dept.; J. Durant, bus. mgr.; O. King, sls. prom. mgr.

DS 261—Newport News Shipbuilding and Drydock Co., Newport News, Va.—Booth 411.
5,000 KWH homogeneous reactor and conceptual design model of cargo ship powered by nuclear reactor.
O. H. Klepper; J. E. Coutts; F. J. Horn; J. C. Smith; R. M. Davis, Jr.

DS 262—North American Aviation, Inc., Downey, Calif.—Booth 608.
Models of North American design research & power reactors.
Bulletins not supplied.
Dr. Starr, v.p. nuc. engr. & mfg. div.; R. Loftness; A. Andrew; D. Howard; M. C. Smith

DS 263—Norton Company, Worcester, Mass.—Booth 427.
Stable boron reactor components for control elements and neutron shields; ceramic and powder-metal fabricated components for fuel elements; special refractories; ceramic raw materials.
Bulletins: Technical booklet on boron and boron carbide.
F. B. Huke, chf. atomic prod. engr.; C. W. Henson, atom. prod. engr.; H. T. Pierpont, sales mgr.; G. A. Finlay, research engr.; O. J. Whittemore, res. engr.

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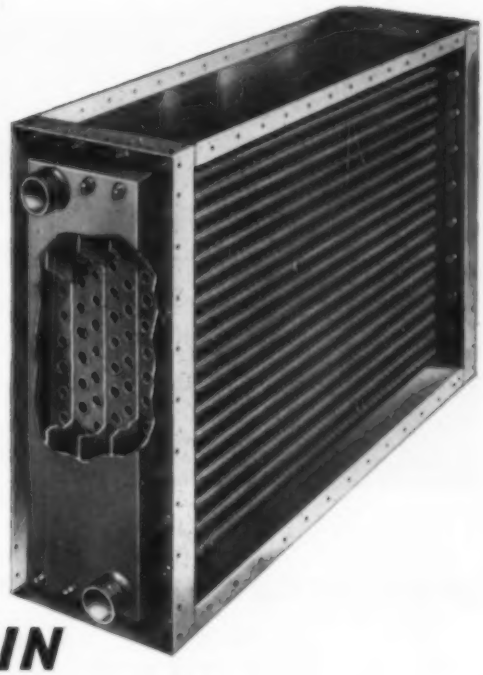

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NUCLEAR CONGRESS *(continued)*

16. Structural Aspects of the Multicurie Fission Products Pilot Plant, H. M. Glen, Oak Ridge (ASCE)

REACTOR ANALYSIS TECHNIQUES

232. Electronic Simulation of Temperature Transients in a Reactor, B. Kaplan and A. F. Mentink, General Electric (AIChE)

233. Analogue for Solution of Heat Conduction Problems, W. R. Simmons, Argonne (AIChE)

234. Analysis of Temperature Transients in a Nuclear Power System, Robert J. Fritz, Knolls Laboratory, General Electric (ASM)

234a. Nuclear Reactor Simulator for Teaching Purposes, L. Orr, W. Kerr, and H. J. Gomberg, U. of Michigan (AIEE)

234b. Use of Computers to Determine Time-dependent Fission-product Distribution, John V. Nehemias, Ralph C. Dennis, John G. Lewis, and Harold A. Ohlgren, U. of Michigan (AIEE)

355. Problems of Mechanical Analysis in Reactor Technology, G. Horvay, Knolls Laboratory, General Electric (ASME)

EXPLORATION AND PRODUCTION

247. Air-borne-radioactivity Surveying: U.S.A,. Frank W. Stead, U. S. Geological Survey (AGI)

247a. Air-borne Methods of Search for Radioactive Mineral Deposits, H. S. Scott (AGI)

General Situation—Uranium Supplies, Jesse C. Johnson (AGI)

250. Geochemistry of Oxidation of the Uranium Deposits of the Colorado Plateau, R. M. Garrels, U. S. Geological Survey (AGI)

251. Application of Stratigraphy to the Search for Uranium Deposits on the Colorado Plateau, Lawrence C. Craig, U. S. Geological Survey (AGI)

252. Genetic Relationships in Uranium Deposits, Donald L. Everhart, A. E. C. (AGI)

Uranium Processing, Dan M. Kentro, A. E. C. (AGI)

341. Organic Geochemistry of Uranium, Irving A Breger, U. S. Geological Survey (AGI)

URANIUM GEOLOGY

Summary Description of Canadian Uranium Deposits, Arthur H. Lang (AGI)

254. Regional Structure and Uranium Distribution on the Colorado Plateau, Vincent C. Kelley, U. of New Mexico (AGI)

255. Uranium-bearing Coal in the Western United States, N. M. Denson, U. S. Geological Survey (AGI)

256. Uranium-bearing Horizons, Thomas W.

ATOMIC EXPOSITION *(continued)*

DS 264—Nuclear Consultants, Inc., Long Island City, N. Y. Booth 602.

Consulting services offered to industry; radiation equipment by NRD Instrument Co.
Bulletins: Describing services, products.
K. H. Morganstern; W. Konneker; J. L. Stone; R. Buntaine; K. Wolf

DS 265—Nuclear Development Corp. of America, White Plains, N. Y.—Booth 112.
Research reactor model; data handling system for inventory control.
W. S. Mott; A. M. Zais

DS 266—Nuclear Instrument and Chemical Corp., Chicago.—Booth 102.
Radiation measuring instrument and scintillation exploration system.
Bulletins: New developments; general catalog.
J. L. Kuranz, v.p., sales; E. Reible; L. G. Grinnell; M. E. Shepherd

DS 331—Nuclear Research Corp., Southampton, Pa.—Booth 318.

Mitcham, International Ranwick, Ltd. (AGI)

257. Australian Uranium Deposits, C. J. Sullivan, Kennco Explorations (Canada), Ltd. (AGI)

South African Uranium Industries, Robert R. Porter (AGI)

FRIDAY, DECEMBER 16

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83. Reactivity Values of Multiple Reactor Control Rods, Raymond L. Murray, No. Carolina State Col. (ANS)

84. Measurement of Neutral Flux in Critical Assemblies, J. L. Crandall, DuPont (AIChE)

86. Exponential Measurements in Heavy-water systems, O. A. Towler, Jr., and J. W. Wade, DuPont (AIChE)

87. Measurement of Lattice Constants in a Two-region Critical Assembly, G. F. O'Neill and B. M. Carmichael, DuPont (AIChE)

ACCELERATORS

166. Trends in the Design of Cyclotrons after 25 Years, Robert S. Livingston, Oak Ridge (ACS)

Machine Sources of Ionizing Energy for Science, Medicine, and Industry, J. G. Trump, M. I. T. (AIEE)

168. A 25-billion Electron Volt Proton Synchrotron, Martin Plotkin, Brookhaven (AIEE)

169. Bevatron Magnet Pulse-timing System, Warren C. Struven, U. of California Radiation Lab. (AIEE)

171. Electron Linear Accelerator as a Pulsed Radiation Source, M. G. Kelliher, J. C. Nygard, and A. J. Gale, High Voltage Engineering Corp. (IRE)

REMOVAL OF FISSION PRODUCTS FROM AQUEOUS SOLUTIONS

172. Removal of Radionuclides from Water by Water-treatment Processes, Roy J. Morton, Oak Ridge National Laboratory, and Conrad P. Straub, Robert A. Taft Sanitary Engrg. Center (AWWA)

Mixed-bed Ion Exchange for the Removal of Radioactivity, H. Gladys Swope, Argonne (AWWA)

175. Processing of High-level Atomic Wastes with a View to Ultimate Disposal, L. P. Hatch, Brookhaven (AWWA)

176. Decontamination of Radioactive Water Supplies, Rolf Eliassen and Robert A. Lauderdale, M. I. T. (AWWA)

DISPOSAL OF RADIOACTIVE WASTES

184. Ultimate Disposal of Radioactive Reactor

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DS 267—Nuclear Science & Engineering Corp., Homestead, Pa.—Booth 410.
Nuclear height gage; fission flux monitor; accelerator-produced isotopes.
Bulletin: Isotope catalogs and brochures.
R. A. Brightsen, pres.; L. R. Zumwalt, oper. v.p.; R. L. Ely, Jr., tech. dir.; P. Kruger, asst. tech. dir.

DS 332—Pall Filtration Co., Glen Cove, N. Y.—Booth 619.

DS 268—Panax Equipment, Ltd. (U. S. Agent, Rice-Peterson Sales Inc., Palo Alto, Calif.)—Booth 228.
Ratemeter; Dekatron scaling equipment.

DS 333—Pfaudler Co., Rochester, N. Y.—Booth 432.

DS 270—Pittsburgh Piping & Equipment Co., Pittsburgh, Pa.—Booth 207.
Fabricated piping and pressure vessels for AEC installation; process piping for general industry.
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R. Emerson; H. Zinkil; F. Thomas; R. Lundgren; A. S. Hamley, Jr.

(Continued on page 79)

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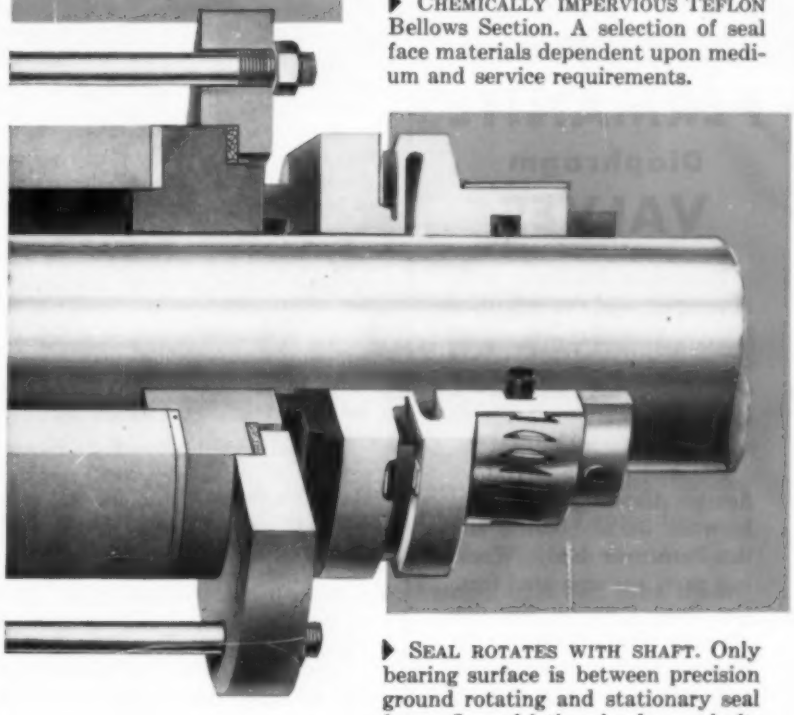
FEATURES

▶ CHEMICALLY IMPERVIOUS TEFLON Bellows Section. A selection of seal face materials dependent upon medium and service requirements.



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REPROCESSING NUCLEAR FUEL— BY DIRECT MAINTENANCE

Idaho Chemical Processing Plant, operated by Phillips Petroleum at the National Reactor Testing Station in Idaho, is first plant to demonstrate the feasibility of processing spent fuel in an installation without remote removal or repair of process equipment.

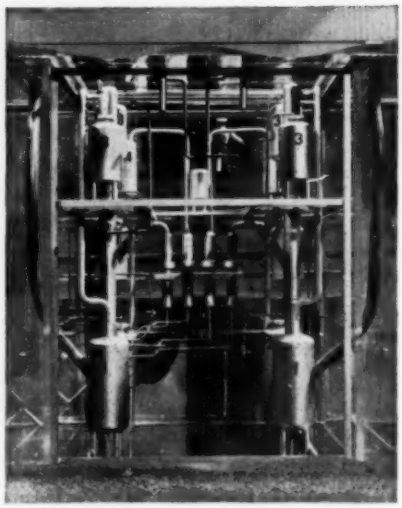
Since it is not possible to burn all the fissionable material from the fuel elements in a nuclear reactor because of the build-up of fission product poisons and radiation damage to the elements, economical operation of a reactor requires that the unconsumed, and highly valuable, fissionable material be recovered. This is, so far, an expensive matter. One of the basic problems has been the difficulty of handling the material to be reprocessed except by use of remote handling instruments.

The Idaho Chemical Processing Plant operated by Phillips is the first designed for direct removal or repair of the process equipment, and is a big step toward more economical processing.

The Process

The basic chemistry of the recovery process at the Idaho plant is simple. First, dissolution of the intensely radioactive uranium-aluminum fuel elements in nitric acid. Second, adjustment of the dissolver solution to a composition suitable for solvent extraction. Third, separation of the uranium from the aluminum, fission products, and transuranic elements by continuous liquid-liquid extraction employing methyl isobutyl ketone (hexone) as the solvent.

The unique feature of the plant, and the one that made the models of it so important at the U. S. Geneva Exhibit, is its provision for direct maintenance. Radioactive material can be washed out of the pipes and tanks so that workers can handle them directly. (In similar plants elsewhere, the equipment remains radioactive and must be worked on with remotely controlled tools.)

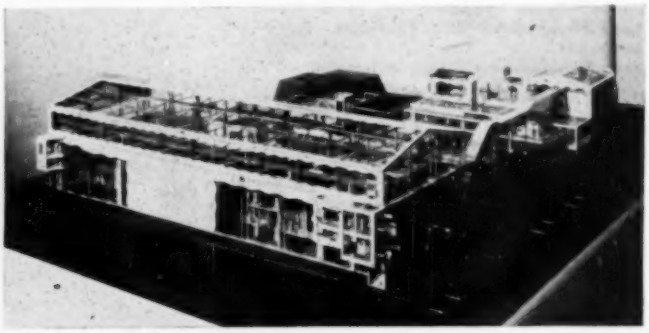


Cell for dissolving used uranium-aluminum fuel elements. (1) are dissolvers, (2) coarse feed adjustment tanks, (3) filters, (4) fine feed adjustment tanks.

In the Idaho plant the equipment is of simple mechanical design for easy decontamination and repair, contains a minimum of moving parts. Critical items, such as transfer jets, valves, and pumps, are installed in pairs, or alternate transfer routes are provided so that failure of one piece of equipment will not require a process shutdown for repair.

Much of the equipment with a high maintenance potential, such as diaphragm-metering pumps and samplers, has been placed in lead shielded cubicles located outside the thick concrete cells where the main process equipment is kept. All equipment is leak-tested and operated on simulated process solutions before actual radioactive processing operations begin.

Stainless steel liners and spray nozzles are provided in the process cells to facilitate external decontamination of the equipment and cells. The direct-maintenance design allows a maximum amount of process equipment to be placed in each cell since no provision has to be made for removal by remote methods.



Simplified model of Idaho Chemical Processing Plant shown at Geneva. Main process building in foreground, waste handling area in background.

ATOMIC EXPOSITION ***(continued)***

DS 334—Porous Plastics Filter Co., Glen Cove, N. Y.—Booth 619.

DS 271—Premier Metal Products Co., New York—Booth 414.
Standard racks; cabinets; chassis and panels for electronic industry.
E. L. Kossoy; J. O. Olsen; F. Mahannah; W. Needles

DS 272—Radiation Counter Laboratories, Inc.—Skokie, Ill.—Booth 217.
Reactor control equip.; double-crystal gamma ray spectrometer; counters; nuclear accessories.
E. H. Wakefield, dir.; C. J. Walsh, sales engr.

DS 273—Ray Proof Corp., New York—Booth 612.
Radiation shielding material and equipment.
Bulletin: Industrial Protection.
S. A. Barnett, pres.; G. R. Brownridge, sec.; R. Aronson, chief engr.; H. C. Hume and A. T. McCulloch, sales office

DS 274—Republic Steel Corp., Cleveland, O.—Booth 516.
Enduro stainless steel and titanium in various forms as fabricated for nuclear reactor use.
Bulletins: Properties data and typical fabrications of stainless steel and titanium.
R. P. Petersen, dir. nuc. res.; V. W. Whitmer, asst. chief metallurgist; G. W. Hinkle, B. J. Keffler; T. E. Perry

DS 276—Sealol Corp., Providence, R. I.—Booth 425.
Rotating shaft seals.
Bulletin: Sealol rotating seals.
C. W. Williamson, pres.; R. Kroekel, res. dir.; J. B. Stevens, chief engr.

DS 279—Sunvic Controls, Ltd. (U. S. Agent, Anglo-Amer. Scientific Corp., Boston)—Booth 228.
Pulse height analyzer; strip chart recorder.

DS 280—Sylvania Electric Products, Inc. Atom Energy Div., Bayside, N. Y.—Booth 223.
Fuel elements shapes for wide cross-section beam nuclear reactors; description of production development facilities; model of reactor for illustrating nuclear fuel dynamics.
Bulletins: Fuels & reactor components data; general activities.
W. E. Kingston, gen. mgr.; S. B. Roboff, mgr., indus. coordin.; H. H. Hausner, mgr., atom. energy engr.; L. Smiley, mgr., tech. coordin.

DS 335—Technical Operations, Inc., Arlington, Mass.—Booth 118.

DS 336—Tektronix, Inc., Cleveland.—Booth 121.

DS 281—Terriss, Div. of Consolidated Siphon Supply Co., Inc., N. Y.—Booth 412.
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NUCLEAR CONGRESS *(continued)*

Wastes in the Oceans, Charles E. Renn, Johns Hopkins U. (AWWA)

185. Status of Soil Disposal for Reactor Wastes, A. B. Joseph, Johns Hopkins U. (AWWA)

187. Design Considerations of Storage Tanks for Radioactive Wastes, E. E. Wilson, DuPont (AIChE)

189. High-level Radioactive Waste Disposal Problems, J. M. Warde, and T. N. McVay, Oak Ridge (ANS)

188. Disposal of Atomic Wastes, Ronald Brightsen, Nuclear Science and Engineering Corp. (ACS)

POLLUTION ASPECTS OF RADIOACTIVE FALL-OUT

182. Long-range Fall-out in Surface-water Supplies, C. G. Bell, Jr., Northwestern U. (AWWA)

Maximum Permissible Levels of Radionuclides in Air and Water, K. Z. Morgan, Oak Ridge (AWWA)

Radioactive Fall-out in the United States, Merril Eisenbud, A. E. C. (AWWA)

Emergency Maximum Permissible Concentration Values in Air and Water, C. P. Straub, U. S. Public Health Service (AWWA)

194. Biological Methods for the Removal of Radioactivity from Liquids, William E. Dobbins, New York U. (AWWA)

190. Radioactivity as a Factor in Stream Pollution, R. C. Palange, G. G. Robeck, and C. Henderson, U. S. Public Health Service (ACS)

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195. Separation of Pro-actinium from Uranium Residue, Murrell L. Salutsky, Kenneth Shaver, Andrew Elmlinger, and Mary Lou Curtis, Mound Laboratory (ACS)

196. Recovery of Uranium from Leach Slurries by Continuous Ion Exchange, I. R. Higgins, Oak Ridge (ACS)

197. Fluoride Volatility Process for the Decontamination of Irradiated Uranium, H. H. Hyman and J. J. Katz, Argonne (ACS)

200. Electrorefining as a Method for Removing Fission Products from Uranium Fuels, Leonard W. Niedrach and Arthur C. Glamm, Knolls Laboratory, General Electric (ACS)

312. Radiochemical Plant Design Philosophy for Direct Maintenance, K. K. Kennedy and D. G. Reid, Phillips Petroleum (AIChE)

NUCLEAR PROPERTIES

202. Pile Neutron Cross Sections of the Heavier Plutonium Isotopes, P. R. Fields, G. L. Pyle, M. G. Inghram, M. H. Studier, and W. M. Manning, Argonne (ANS)

203. Slow-neutron Activation Cross Sections of Several Elements, W. A. Brooksbank, Jr., G. W. Leddicotte, W. S. Lyon, and S. A. Reynolds, Oak Ridge (ANS)

204. Half-lives of Several Radionuclides, H. W. Wright, E. I. Wyatt, S. A. Reynolds, and W. S. Lyon, Oak Ridge (ANS)

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Gas-cooled Liquid Metal Fuel Reactor, H. L. Falkenberry, C. J. Raseman, et al., Brookhaven (ASME)

329. Acid Leaching of Uranium Ores, R. J. Woody and D. R. George, National Lead (AIME)

331. Newer Laboratory Developments for the Recovery of Uranium from Colorado Plateau Ores, A. M. Ross, H. G. Petrow, and P. Galvanets, Jr., National Lead (AIME)

279. Program of Radioactivity Surveys in Petroleum Exploration, Frederick H. Lahee, Sun Oil (AGI)

358. Petroleum Exploration Methods as Applied to Uranium Exploration, R. A. Broding and Ben F. Rummerfield, Century Geophysical Corp. (AGI)

URANIUM DEPOSITS

281. Uranium Deposits of the Big Indian Wash-Lisbon Valley Mining District, San Juan County, Utah, Y. William Isachsen, A.E.C. (AGI)

Black Hills Uranium Deposits, James O. Harder (AGI)

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286. Uranium Deposits of the Algoma (Blind River) District, Ontario, 1955, Franc R. Joubin, Algom Uranium Mines, Limités (AGI)

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289. Determination of Pile Constants by Chemical Methods, C. E. Crouthamel, Argonne, and E. Turk, Phillips Petroleum (ACS)

290. Synthesis of Thorium 228 from Actinium 227, H. W. Kirby, G. R. Grove, and D. L. Timma, Mound Laboratory (ACS)

291. Properties of Plutonium Hexafluoride, Bernard Weinstock and John G. Malm, Argonne (ACS)

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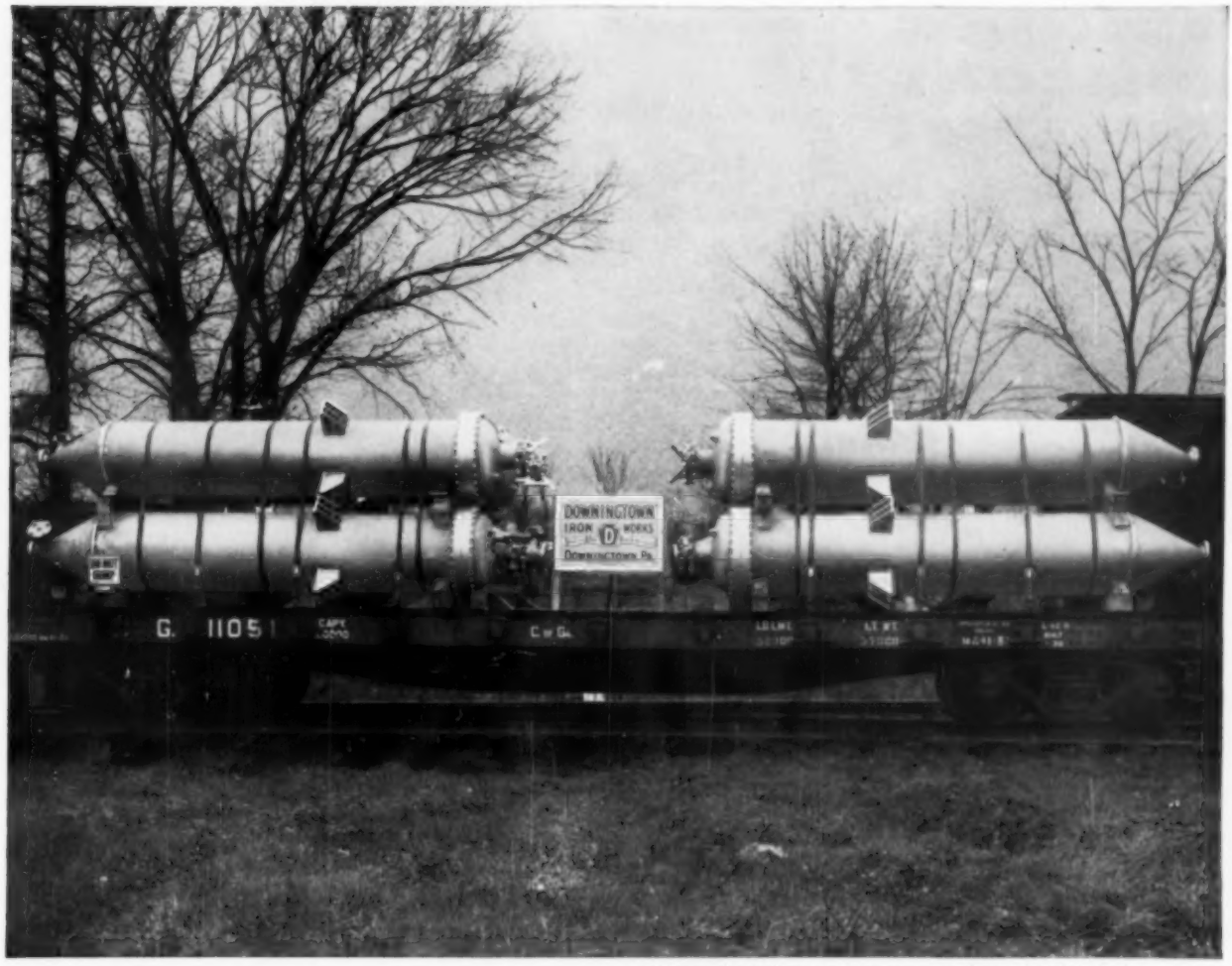

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INDUSTRIAL NEWS

CHEMICAL TANK FIRES —"DROWN" THEM

New tank fire control method developed by Koppers Company "drowns" fire in its own "fuel."

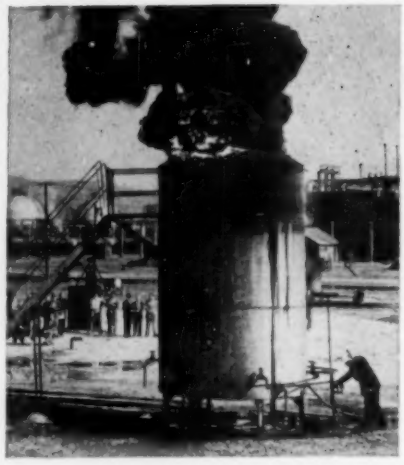
In a recent demonstration, Koppers Company extinguished a raging fire in an 8,000 gallon tank of coal chemicals in less than 30 seconds by actually drowning the flames in the cooler chemicals from the bottom of the tank.

Deliberately firing the tank of chemicals, Kopper's safety engineers put the fire out by utilizing the principle of circulating enough cold chemicals, quickly enough, to reduce the temperature of the overall liquid below its flash point.

The demonstration climaxed two years of development of a system of controlled agitation which had never previously been adapted to fighting fires in coal chemical tanks, although J. L. Risinger of Socony-Vacuum had done considerable work along this line.

Versatility is one of the prime advantages of the new system. Agitation, key to the method, was accomplished by several different techniques. In separate tests, compressed air and nitrogen were successfully used, despite the fact that air ordinarily will spread flames, intensify the fire.

In one demonstration the fire was extinguished using only compressed air through the normal inlets provided to assist in regular mixing operations.



Another method shown, one completely unique to Kopper's developments, was agitation by recirculation of the liquid in the tank itself. This was done by pumping liquid from, and then back into, the tank through a jet mounted in the center bottom of the tank and directed upwards. By this alternate in and out pumping the liquid stirred itself.

In all twelve tests with burning creosote oil, complete extinguishment was obtained. Demonstrations were then made with even more volatile chemicals. When these were ignited it was not always possible to extinguish them completely, but excellent control was obtained, enabling ordinary fire-fighting equipment to rapidly finish the job.

ATOMIC EXPOSITION *(continued)*

automatic controls; liquid level gauges and equipment for industrial radiography.
Bulletins: Literature on all exhibits available.
H. Myers, mgr. Indus. Div.; T. Kelley, mgr., Instrument Div.; W. McCarthy, sales engr.; G. McKewen, prod. mgr., indus. div.

DS 339—Union Carbide & Carbon Corp., New York—Booth 220.

DS 285—Universal Atomics Corp., New York—Booth 103.
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Bulletins: Universal Atomics and its products.
J. Gannon; S. Katz; A. Bender; M. Goodman

DS 340—Victoreen Instrument Co., Cleveland.—Booth 213.

DS 341—Vitro Corporation of America, New York—Booth 111.

DS 342—Wagner Electric Corp., St. Louis, Mo.—Booth 509.

DS 287—Westinghouse Electric Corp., Pittsburgh, Pa.—Booth 332.
Model of atomic power plant; hermetically sealed motor-driven pump; radiation detecting apparatus.
Bulletins: not supplied.
W. D. Shepherd, sales mgr. Commerc. Atomic Power; L. G. Hauser; sales mgr. Atomic Equip. Dept.; C. V. Roseberry, mgr., Comm. Atomic Power

DS 288—Weston Electrical Instrument Corp., Newark, N. J.—Booth 324.
Magnetic relays; panel instruments; thermometers; recorders, etc.
Bulletins: Weston in field of nuclear energy.
R. T. Pierce, Spec. Service admin.; R. W. Gilbert, asst. to pres.; L. Van Blerkom, sales mgr.; R. O. Matthes, Sales Dept.; O. N. Jones, Admin.

DS 257—Murphy Radio, Ltd., Herts, Eng.—Booth 228.

DS 269—Phoenix Memorial Project, Ann Arbor, Mich.—Booth 228.
Display showing facilities employed in large private project.

DS 275—Scientific Instrument Mfrs. Assoc. of Gr. Britain, London, Eng.—Booth 228.

DS 277—Sellers Injector Corp., Phila.—Booth 438.

DS 278—R. A. Stephen & Co., Ltd., Surrey, Eng.—Booth 228.

DS 284—Trumpeter Co., Ltd., Manchester, Eng.—Booth 228.

DS 300—20th Century Electronics, Ltd., Surrey, Eng.—Booth 228.

DS 286—D. Van Nostrand Co., New York—Booth 96.
Nuclear Science Books.

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GROUP	I.	II.	III.	IV.	V.	VI.	VII.	VIII.			I.	II.	III.	IV.	V.	VI.	VII.	VIII.
1	H																	He
2	**Li**	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	A
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Rare Earths	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac Series	**Th**	Pa	**U**	Np	Pu	Am	Cm	Bk	Cf					

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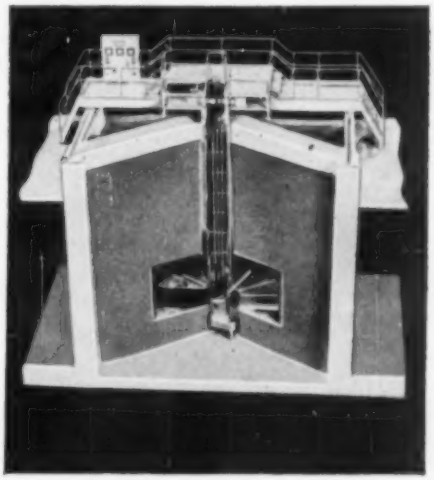

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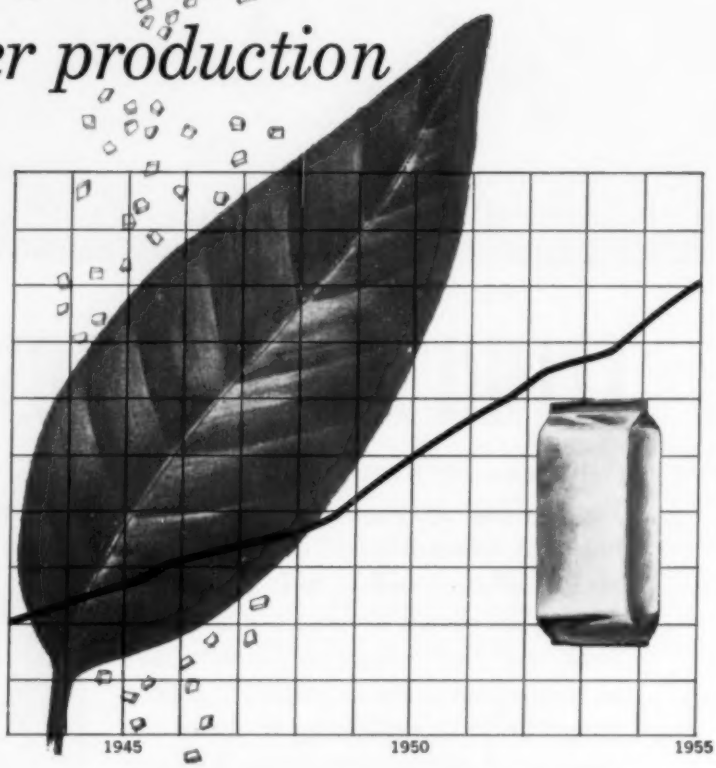

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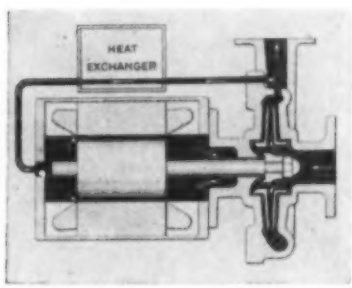

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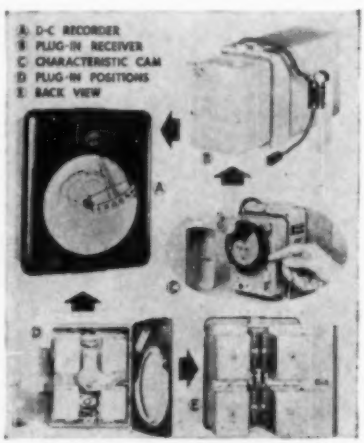
42L Demisters. Use of Yorkmesh demisters in process vessels provide separation of 99.9% using high vapor velocities. Negligible pressure drop. Otto H. York Co., Inc.

43A Refractories. Fusion-stabilized products for the atomic program will be displayed by Norton Co. at the Atomic Exposition, in addition to their regular line.

44A Autoclave Valves. Submarine Nautilus carries in her hull special valves from Autoclave Engineers, Inc. Same engineering skill is available for application to your needs.

DEVELOPMENTS OF THE MONTH *(Cont.)*



102. It is now possible to combine four records from d-c pickups, a-c pickups, or pneumatic transmitters on the same uniformly-graduated, circular chart.

Making this possible is the new Bailey Electronic Receiver Recorder for telemetering systems. It eliminates the expense of individual recorders, special charts, conserves expensive panel space, provides equal reading accuracy at any point on the chart, improves record analysis.

Receiver ranges are 0-2 millivolts to 0-20 volts d-c. Error is less than ¼% for spans of 10 millivolts or more, 25 microvolts for lower spans. Sensitivity is 0.05% for all spans.

The recorder may house as many as four plug-in, d-c receivers, or two receivers and two pneumatic controllers.

For detail circle number 102 on Data post card.

(Continued on page 88)

45A Radiation Shielding. Lead shielding against radiation, manufactured for any requirement. O. G. Kelley & Co.

46A Heat Insulation. Called Thermobestos material has combination of properties excellent for temperature control. Johns-Manville.

47A Filters. If Snap Blow is practical for the product you are filtering you may order it on your Elmco Corp. Filter. Saves filter media & down time.

48A Stainless Steel. Plates, heads, & other stainless products cut & machined by the fabricator save freight charges. G. O. Carlson, Inc.

50A Refinery Plant. Expansion & modernization of existing installations engineered & built by Blaw-Knox Co.

52A Petrochemicals. Years of experience in building chemical plants makes it advantageous to consider M. W. Kellogg Co. when expanding to include petrochemicals.

Mechanical Seals Bulletin—See item number 55 on page 92.

53A Turbo-Mixers. From asphalt filling to xylene extraction production flows faster with a Turbo-mixer on the job. General American Transportation Co.

54A Vacuum Furnaces. Vacuum metallurgy improves high-temperature characteristics & purity of nickel, steel & copper. Catalog available. F. J. Stokes Machine Co.

55A Reactors. Fabricated from glassed steel, equipment for atomic plants. Many new ideas in corrosioneering. Pfaudler Co.

56A Process Plants. From design through construction to operation the entire project can be successfully handled by the Girdler Co.

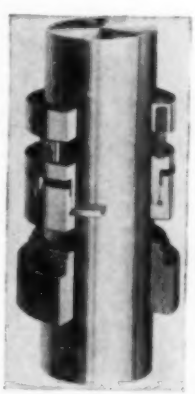
60L Heat Exchangers. Standard stainless Steel heat exchangers for rigid use in petroleum, chemical, & petrochemical fields. Doyle & Roth Mfg. Co., Inc.

61A Radiation Detector. Called Librascope BIC-2 unit features quick, accurate measurement of radiation from .05 to 50 Roentgens/hr. Librascope.

62L Process Equipment. Boilers, kettle, reactors, other like equipment designed & fabricated for your specific need. Manning & Lewis Engineering Co.

63R Air Conditioning. Exact control of moisture content by the Niagara Blower Co. air conditioning method dries air directly & measurable using a moisture-absorbing liquid spray.

65A Heat Transfer. Heat control by use of the Dowtherm is discussed in the "Dowtherm Handbook" from Dow Chemical Co.



Dura Seals—See item number 97 on page 92.

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

Please do not use this card after January, 1956

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Advertisers' Products

IFC	3R	4A	5A	6L	7A	8A	9A	10L
11A	12A	13A	14A	15A	17A	18A	19-20A	21A
22A	23A	24L	25A	26A	27A	28A	29A	30A
31A	32L	33A	34A	35A	36A	37-38A	39A	40A
41A	42L	43A	44A	45A	46A	47A	48A	50A
52A	436A	53A	54A	55A	56A	60L	61A	62L
63R	65A	66L	67R	68A	73A	75R	76L	77R
78L	79R	80L	81A	82L	83A	84A	89A	93R
94L	94R	95R	96L	97R	98L	99R	100L	100R
101TR	101BR	102L	104L	105TL	105BL	105R	106L	107TL
107BL	107TR	107BR	109TR	109BR	110L	111TL	111BL	111R
113TR	113BR	114TL	114BL	115TL	115BL	115R	116TL	116BL
121TR	121BR	122L	123R	1BC	OBC			

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

October, 1955

First section of card for *Atomic Exposition items*

Please do not use this card after January, 1956

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This section for Advertisers' Products in issue.

IFC	3R	4A	5A	6L	7A	8A	9A	10L
11A	12A	13A	14A	15A	17A	18A	19-20A	21A
22A	23A	24L	25A	26A	27A	28A	29A	30A
31A	32L	33A	34A	35A	36A	37-38A	39A	40A
41A	42L	43A	44A	45A	46A	47A	48A	50A
52A	436A	53A	54A	55A	56A	60L	61A	62L
63R	65A	66L	67R	68A	73A	75R	76L	77R
78L	79R	80L	81A	82L	83A	84A	89A	93R
94L	94R	95R	96L	97R	98L	99R	100L	100R
101TR	101BR	102L	104L	105TL	105BL	105R	106L	107TL
107BL	107TR	107BR	109TR	109BR	110L	111TL	111BL	111R
113TR	113BR	114TL	114BL	115TL	115BL	115R	116TL	116BL
121TR	121BR	122L	123R	1BC	OBC			

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

October, 1955

products-(Cont.)

66L Slime Control Equipment. Whether you heat or cool water for process use chlorination aids in slime control. Wallace & Tiernan chlorination increases efficiency.

67R Filters. From start to end of cycle constant filtering quality is maintained using Sparkler horizontal plate filters. Sparkler Mfg. Co.

68A Air Preheater. Ljungstrom preheater reduces slag, stays on stream at top capacity longer. Saves by cutting turnaround time. Air Preheater Co.

73A Controlled-Volume Pump. If yours is a problem of corrosion the Lapp Pulsafeeder a controlled volume pump operates without leakage or contamination. Lapp Insulator Co., Inc.

75R Aerofin Coils. Removable header water coils which assure complete drainability, easy maintenance & high heat transfer. Aerofin Corp.

76L Research Laboratories. Are you planning new research laboratories? If you are, Wigton-Abbott Corp. specialists in the field will welcome your inquiry.

77R Mechanical Seal. The pressure-balanced bellows design seal made of impervious Teflon offers drop-tight service. Sizes ⅞ to 2⅛ in. United States Gasket Co.

78L Diaphragm Valves. Made of Permanite a furan resin developed by Maurice Knight Co. valves offer high corrosion resistance. Operating temperatures 180 to 220°. Sizes 1 to 3 in. bore.

79R Maintenance Service. This service puts a crew of maintenance experts at your command any day, night, Sunday, or holidays. Investigate. Condenser Service & Engineering Co., Inc.

80L Rupture Proof Switch. For flow, liquid level or differential pressure. Available with variety of contacts. Instrument Corporation.

81A Process Tanks. Tanks are only one of many products fabricated by Downingtown Iron Works, Inc. Thoroughly experienced in working & welding many alloys, metals, & carbon & stainless steels.

82L Silicone Defoamers. Proven efficiency & versatility in countless examples. Booklet gives complete information. Dow Corning Corp.

83A Lithium. In the atomic future lithium has a prominent place. You may share the benefits of research on this material by writing for technical data sheets. Lithium Corporation of America, Inc.

84A Phosphoric Acid Plants. Using the low-cost St. Gobain-Union Chimique Belge process Fluor Corporation Ltd. will design & erect phosphoric acid plants the key to profitable fertilizer production.

89A Packaged Pilot Plants. Standard models with internal contact surfaces of stainless steel, in capacities of 5, 10, or 15 gallons. Patterson-Kelley Co., Inc.

93R Pressure Vessels. Long experience results in the best in design & fabrication of pressure vessels. Consult Industrial Process Engineers.

94L Process Equipments. You can make simple work of filtering, mixing, storing with a saving in time, space, & labor, by use of custom fitted equipment. Alsop Engineering Corp.

94R Graders. The facts about accurate sizing may be had by visiting the Hart-Carter Co. exhibit Booth C-18 at the Chem Show. Various machines demonstrated.

95R Castings. Alloy castings of 18.8 for under rugged conditions of corrosion & temperature. Available are static sand, centrifugal & shell molded castings. Duraloy Co.

96L Dryers. A new type of housing construction in tunnel truck dryers offers added advantages in speed of erection & smoother, easy-to-clean interiors. Proctor & Schwartz, Inc.

97R Pressure Vessels. Large & small size pressure vessels in steel & alloy steels for liquid & gases. Designed & fabricated by Posey Iron Works, Inc.

98L Filter Paper. Employ the know-how of Eaton-Dikeman Co. in selecting filter paper, a firm devoted exclusively to its manufacture. Samples available.

99R Evaporators. A falling film design evaporator designed for economy & efficiency. Whitlock Mfg. Co. also builds all types of heat exchangers. Recommendations available.

100L Bag Closer. Fast, secure, low cost bag closing assured by the use of this portable bag closer which weighs but 10½ lb. Dave Fischbein Co.

100R Ion Exchange. Purification of water by the ion exchange method is the reliable way. Now it functions with wastes contaminated by radioactivity. Illinois Water Treatment Co.

101TR Radiation Monitor. For exploration in industry & medicine a scintillation detector with 200 times the sensitivity of a Geiger counter. La Roe Instruments, Inc.

101BR Sprocket Rim. Equipped with chain guide this redesigned unit makes every valve easily accessible. Simplifies pipe layouts. Babbitt Steam Specialty Co.

102L Process Equipment. Process equipment which is heat & corrosion resistant designed, developed & built by Misco Fabricators Inc.

104L pH & Chlorine Control. Factual data on theory & application of pH, chlorine, phosphate, & nitrate control contained in booklet from W. A. Taylor and Co.

105TL Pulse Height Analyzer. A twenty channel differential analyzer with Bell-Kelley circuits. Completely electronic test pulse generator. Detectolab, Inc.

105BL Bonding Agent. Helix bonding agent R-385 is a one component epoxy based metal adhesive. Gives strength of 3,500 lb./sq.in. between metal parts. Carl H. Biggs Co.

105R Valves. Fabricated from a full range of metals valves handle most things piped. Many applications in processing. DeZurik Shower Co.

106L Flexible Couplings. Maintenance-free service up to 15 years is not unusual for these units. Simple construction, no intricate mechanisms. Lovejoy Flexible Coupling Co.

107TL Filters. Double filtration is featured in the new pyrogen & bacterial filters from Ertel Engineering Corp. Precision machined, units are easy to set up & clean.

107BL Plastic Pump. Vanton Pump & Equipment Corp. plastic pump has no stuffing box, gasket, or shaft seals. Pumps corrosive liquids & abrasive slurries with ease.

(Continued on page 90)

DEVELOPMENTS OF THE MONTH (Cont.)

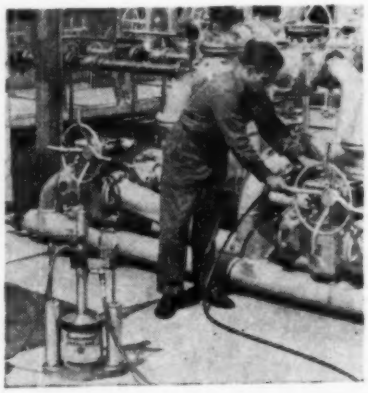
101. The only positive self-priming plug valve lubricant gun on the market today is the new, compact, lightweight air-operated gun just introduced by Rockwell Manufacturing Co.

Designed to meet field and plant maintenance needs, the new "Hypregun" weighs only 39 pounds, operates on air pressures up to 150 lbs./sq.in.

A specially designed air motor and double piston construction provide the self-priming action, one of the gun's outstanding features.

The gun uses Rockwell-Nordstrom five quart lubricant cans loaded directly into it, eliminating all manual handling of lubricant or changing lubricant from one container to another.

For further information circle number 101 on Data post card.

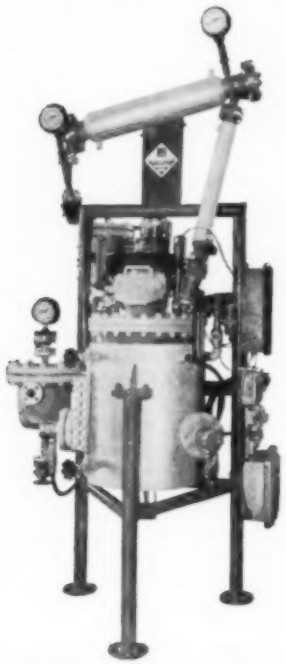


(Continued on page 90)

need a packaged Pilot Plant?

Now you can choose from a line of *standard* models... with internal contact surfaces of stainless steel... in capacities of five, ten or fifteen gallons... heated by steam, gas, or electricity. Each is equipped to handle a wide range of temperatures, pressures, rates of flow, and other physical variables.

Beyond this "standard" flexibility, each model can be readily adapted to fit even more specialized needs. By checking this line first, you can save original design cost and cut engineering and delivery time.... Here are two pilot plants and an autoclave already tested "on the job"...



15 GALLON PILOT PLANT

Design pressure for all vessels, jackets and piping 150 PSIG and full vacuum. Internal contact surfaces stainless steel, ground smooth.

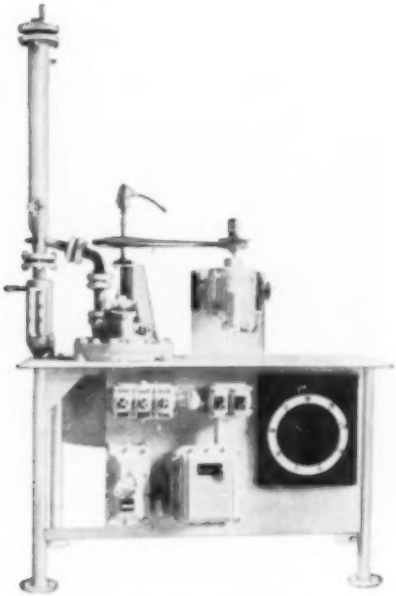
KETTLE: Jacketed sides and bottom for cooling and Dowtherm heating. Reactor designed for 700°F. Variable speed agitator.

CONDENSER: Removable core type. Water cooled shell.

DECANTER: Removable top head.

RECEIVER: 5 gallons capacity. Removable top head.

INSTRUMENTATION: Temperature recording controller and pressure indicator on reactor. Indicators for pressure, liquid level, temperature on reactor jacket. Other indicators on condenser, decanter, receiver. Flow indicator in condenser discharge piping.



5 GALLON DISTILLATION PILOT PLANT

Designed as a complete packaged unit for alkyd resin experimentation. Active surfaces of stainless steel, ground smooth.

REACTOR: 150 PSIG design pressure. Internal cooling cylinder. Thermostatic controls. Variable speed agitator with hollow shaft for injection of gases into material.

CONDENSER: Arranged to operate in any position.

DECANTER: Stainless steel. Sight glass.

INSULATION JACKET: Arranged to protect main body of vessel as well as to service electric heaters.

10 GALLON LAB AUTOCLAVE

Vertical design with removable top cover, stainless steel internal surfaces.

AUTOCLAVE: Designed for full vacuum pressure.

JACKET: Designed for 100 lb. pressure.

AGITATOR: Speed of 34–138 rpm. p-k Agitator 15" diameter.

Want a quotation? complete specifications . . . ? We'll be happy to send you more information on these and other units in p-k's wide line of research, development and production equipment for the processing industries. Send us your question, specific or general.

The Patterson-Kelley Co., Inc.

1800 Lackawanna Avenue, East Stroudsburg, Penna.

2552

101 Park Avenue, New York 17 • Railway Exchange Building, Chicago 4 • 1700 Walnut Street, Philadelphia 3 • 96-A Huntington Avenue, Boston 16 • and other principal cities.

products-(Cont.)

107TR Spectrometer. A single channel, scintillation pectrometry system provides stable & reproducible analysis for use in medical, food, & other fields. Atomic Instrument Co.

107BR Ovens. For innumerable applications these ovens available from stock or custom built. Temperatures to 1,200° F. Grieve-Hendry Co., Inc.

109TR Desiccant. If you are planning erection of a petrochemical plant consider Florite desiccant. Absorbs water instantly from gases or liquids in static or flowing systems. Floridin Co.

109BR Filters. Airpure filters specify 99.5% efficiency on particle sizes of 0.3 microns the result of accurate test equipment. Flanders Mill Inc.

110L Filters. Sintered glass filters have increased hardness thus providing longer life. No contamination due to detachment of filter particles. Ace Glass Inc.

111TL Dosimeter. Called Radad a major exposure dosimeter that gives cumulative measurement & instantaneous reading. Electromation Co.

111BL Research. Research which solves problems is offered by Foster D. Snell, Inc. Inquiries invited without obligation.

111R Photochemical Equipment. If yours is a problem of synthesis, decomposition, or other phase of production Hanovia Chemical & Mfg. Co. photochemical equipment may effect savings.

113TR Blenders. Systems blends two or more liquids in preset proportions, automatically in continuous production. May be integrated with packaging & accounting units. Bowser, Inc.

113BR Atomic Science. Atomic Development Securities Co., Inc. provide managed investment in companies participating in the atomic scene.

114TL Skin Protection. Kerodex a cream which acts like glove provides effective protection against skin irritants encountered in industry. Ayerst Laboratories.

114BL Coolers. Refrigerated coolers for chemical process liquids plus Freon-12 vaporizers, offered by Richard M. Armstrong Co.

115TL Arched Wafers. Your product in the form of arched wafers has many advantages over flakes & other shapes. Flakice Corp.

115BL Homogenizer. For high speed intensive blending & refining of pulps, slurries, liquids & solids the Gruendler No. 24 turbo-homogenizer. Data available. Gruendler Crusher & Pulverizer Co.

115R Pla-Tank. Molded from long-life resin-bonded glass fiber laminate unit resists wide variety of contaminants. Pla-Tank, Inc.

116TL Piping. Process piping in any size, diameters to 60 in., & in any shape. Wall thicknesses to ⅜ in.; temperatures to 2,200° F. Pressed Steel Co.

116BL Process Equipment. All types whether portable or built in, & for all purposes designed & fabricated by Arthur Colton Co.

121TR Fittings & Flanges. Fabricated from PVC these injection-molded parts provide good corrosion resistance. Handle chemicals to 165° F. Tube Turns Plastics, Inc.

121BR Nozzles. Flay Spray, hollow cone or full cone nozzles, whatever your need write for nozzle catalog. Spray Engineering Co.

122L pH Meter. An analytical pocket pH meter & revolutionary probe unit enables you to make instant pH readings anywhere. Analytical Measurements, Inc.

123R Evactor Units. Mutli-stage steam jet Evactor units maintain industrial vacuum to 99.99% of perfect. Others maintain vacuum at any desired point. Croll-Reynolds Co., Inc.

436A Tygon Plastic. For use in sheets, as tubing, & other forms Tygon plastic is so flexible it folds in your hands. Tubing in bores .120 to 2 in. is glass clear. U. S. Stoneware Co.

IBC Fin Tubes. High pressure heat exchanger sections from Brown Fintube Co. now operate with high efficiency in many petrochemical plants.

OBC Mixers. Accuracy in fluid mixing easily accomplished by specifying Lightnin mixers. Literature available. Mixing Equipment Co., Inc.

DEVELOPMENTS OF THE MONTH (Cont.)

103. Want to get the "feel" of a nuclear reactor, learn how it works, actually "operate" it without ever going near an actual installation or building one? Then it might pay you to look into the new Leeds & Northrup Nuclear Reactor Simulator.

The heart of this highly valuable unit is an analog computer which solves continuously the differential equations which represent the kinetic operation of a nuclear reactor. In addition the simulator is provided with a full-size control panel, having all the recording instruments, amplifiers, meters, switches, and other gear of a real reactor.

To make the simulator even more "real," there is a scale-model of a reactor core, complete with the familiar lattice, the movable rods that move up and down in response to the controls at the panel and to operating conditions "simulated" by the equipment's analog computer. There is even the familiar blue glow of the Cerenkov effect so characteristic of reactor operation at higher power levels.

The trainee can learn the principles of reactor theory and performance, see graphic demonstration of the complex kinetic equations involved, and can actually "see" the results of altering certain variables.

For further details circle number 103 on Data post card.

materials-

1 Heat Transfer Fluids. From Carbide and Carbon Chemicals Co. technical data sheet on Ucon heat transfer fluids. Differ in nature & performance from natural oils & synthetics for this use. Have remained unchanged for months at 500° F in closed vented systems.

2 Activated Alumina. New product data sheet available from Reynolds Metals Co. Material is compound of aluminum & oxygen with interesting characteristics. Inert to most chemicals. Used for drying gases & liquids.

3 Silicones. Silicones, their intermediates & monomers available from Linde are subject of available bulletin. For use in experimental or commercial development.

4 Polyethylene Resins. Grade numbers on Petrothene polyethylene resins from U. S. Industrial Chemicals have been realigned into three groups 100, 200 & 300 series, according to use. Property data & samples available.

5 Sintered Metallic Oxides. Alites based on aluminum oxides & developed by U. S. Stoneware Co. covered in folder. Of interest to investigators using high temperature ceramics in mechanical, chemical & electrical applications.

6 Sorbic Acid. Carbide and Carbon technical bulletin on food grade sorbic. Controls growth of yeasts & molds. Physical properties, solubilities, etc. listed.

7 Waste Treatment. A process data sheet from Leeds & Northrup Co. outlines late developments for control of pH and redox. Discusses controllability factors reported to influence automatic measurement & control of pH.

8 Protective Coating. Called Dimetcote No. 3 an inorganic protective coating from

materials-(Cont.)

Amercoat Corp. Leaflet lists general, physical & chemical properties. One coat gives steel surfaces required protection over long period.

9 Plasticizer 84. This octyl butyl phthalate plasticizer for use in nitrocellulose formulations said to provide good permanence properties & improved cold check resistance. Eastman Chemical Products, Inc.

10 Polyethylene. An 8-page brochure from Allied Chemical & Dye Corp. lists advantages of low molecular weight A-C polyethylene. Beneficial in rubber compounding by reduction of shrinkage, increased gloss, good electrical properties, & improved compatibility.

11 Copolymer Emulsion. Called Vinac Flexbond 800, this new polyvinyl acetate copolymer emulsion now in full production by Colton Chemical Co. Used for formulating primers & sealers, interior & exterior paints, remains permanently flexible. Will not blister or peel. Samples, data sheets & specifications available.

12 Nylon Molding Compounds & Polyethylene Lubricants. Plaskon compounds 8200 & 8201 are covered in brochure from Barrett Div., Allied Chemical & Dye. Features are high molten viscosity, lower molding temperatures, unique, controllable crystalline structure with excellent colorability.

14 Acrylic Esters. Carbide and Carbon technical bulletin available on acrylic esters concerns itself with methods of polymerization, applications of polymers & copolymers, plus selected references. Physical & chemical properties, also reactions included.

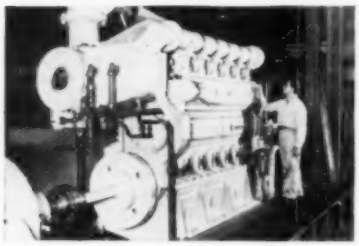
15 PVC Fabrications. Many items fabricated from PVC by Haveg Corp. are covered in available brochure. Recent information on chemical resistance, properties & formation procedures. Also specifications on pipe & pipe fittings & other finished products.

16 Polyethylene. American Agile Corp. 8-page illustrated booklet "Plastics for Chemical Engineering Construction—Polyethyelne," details molecular structure & discusses properties & characteristics.

17 Surface Active Agents. Air Reduction Chemical Co. announces availability of technical bulletin on Surfynols non-foaming, non-ionic surface active agents. Give improved wetting when combined with other surfactants.

18 Styrene Resin. Introduced by Goodyear Tire & Rubber Co., Inc. a thermoplastic modified high styrene resin called Plio-Tuf C75. Designed for use as a processing calendering resin with good heat stability.

DEVELOPMENTS OF THE MONTH (Cont.)



104. Need a low-capacity, heavy-duty continuous service automotive type engine in a smaller size?

If you do, Worthington has a specially designed engine to just fill the bill. Called the W9, the new engine has a 9-inch bore, 11-inch stroke, is a four cycle 400-1400 hp engine for speeds up to 1000 rpm.

Intended for chemical and petroleum plants, among other uses, the engine has been designed for power take-off from either end. It can be equipped with any of the standard clutches, torque converters, or other power take-off equipment.

A main feature of the new motor is its "Jet-swirl" feature. The intake passages are designed to impart a turbulent swirling motion to the air as it enters the cylinder, assuring intimate rapid mixing of the air and fuel. This accounts for low fuel consumption, high power output.

For further details circle number 104 on Data post card.

105. A cumulative collection of descriptive and technical data on all aspects of the building and operation of chemical plants, kept up to date, published by a company fully experienced in the field. This new literature series, called The Chemical Plants Reference File, published by Chemical Plants Division of the Blaw-Knox Co.

The information, presented on classified file sheets, is based on the experience of Blaw-Knox in engineering, design, procurement, and construction.

Included in the sheets will be process descriptions, performance data, flow diagrams, economic studies, data on expanding or modernizing existing facilities.

For details circle number 105 on Data post card.

bulletins-

20 Transducer. Called Vibrotron a miniature variable frequency transducer from Byron Jackson Co. Unit is simple, accurate, has builtin calibration, ideal for long distance transmission & rugged service. Folder from Electronics Div.

22 Boilers & Generators. Edge Moor Iron Works bulletin on water tube boilers & steam generating equipment covers the various types available, plus auxiliaries.

23 Mixers. Industrial mixers both vertical & side entering are described in folder from Conn and Co. Vertical units ¼ to 25 h.p.; side-entering from ½ to 30 h.p. Recommendations available on request.

24 Heating Units. A new kind of electrical heating unit called Heatflex for wide range of uses such as heating, deicing, pipe-tracing, etc. Copper construction, withstands to 480° F. in continuous operation & can be produced in wide range of lengths to meet all heating requirements. Well illustrated bulletin.

26 Petroleum Hydrocarbons. A booklet of vapor pressure charts for petroleum hydrocarbons now available from the American Petroleum Institute. Authored by members of Esso Research and Engineering staff.

28 Recorders. Brush Electronics Co. recording instruments of all types & for every use are covered in their bulletin. Each illustrated unit fully described. Descriptive literature or engineering assistance on specific problems available.

29 pH Guide. Available from Beckman Instruments, Inc. a new pH buyer's guide. Shows pictorially which components replace older units & how older & newer components can be used together. Includes a cross-reference chart to simplify electrode selection & tells how to order pH equipment.

30 Oxygen Analyzer. A technical bulletin on the application of Model 282 B dissolved oxygen analyzer from Arnold O. Beckman, Inc. has been compiled & published. Instrument was developed to meet requirements of modern power plants for quick, convenient & precise method continuous measurement of dissolved oxygen in boiler feedwater.

31 Seamless Tubing & Pipe. A data folder published by Babcock & Wilcox is of interest to engineers & designers using stainless tubing & pipe. Touches on attributes of stainless steel & how it can be fabricated.

33 Molybdenum Disulfide Lubricants. A 4-page 2-color brochure describes pioneering in lubrication's fringe area which led to development of this material. Research facilities at Stamford, Conn. as well as German laboratory pictured in folder. Alpha Molykote Corp.

35 Exhausters. Corrosion resistant for handling gases & fumes these units are made in two types. Housings & impellers of Haveg 41 or Haveg 60 resist damage by vibration or direct blows. Unaffected by thermal shock or temperatures to 265° F. Haveg Corp.

36 PVC Pipe & Tubing. Catalog from Saran Lined Pipe Co. illustrates fabrications from Saran, a polyvinylidene chloride plastic. Outstanding characteristic of material is degree of chemical & solvent resistance. All pertinent details.

37 Magnetic Traps. Permanent magnetic Ferrotraps for use with liquid process equipment said to be ultimate in protection against fine & tramp iron contamination. Folder shows cutaway views discusses care & installation, other aspects. Eriez Mfg. Co.

38 Flexible Couplings. A well illustrated catalog from Ajax Flexible Coupling Co., Inc. covers protection, design, applications, detailed descriptions of various available types including special designs. For use on generators, pumps, compressors, winches.

bulletins-(Cont.)

39 Valves. A 4-page circular covers corrosion resistant valves; a 36-page catalog covers iron & steel lubricated plug valves fabricated by Wm. Powell Co. Detailed illustrations of single, screwed & bolted gland types. Physical data on dimensions & ratings.

40 Temperature Control. A technical bulletin on "Precise Temperature Control System for High Pressure Tube Reactors," from Pressure Products Industries, Inc. Prepared by a qualified physicist, it discusses little known topic.

41 Automatic Valves. Schade Valve Mfg. Co. automatic regulating valves for liquid level & pressure regulation illustrated in new folder. For operating conditions under pressures to 600 lb./sq.in. & temperatures to 750° F. All wearing parts renewable or easily machined.

42 PVC Fittings & Flexible Tubing. Introduced by Tube Turns Plastics, Inc., instrumentation fittings made of unplasticized PVC. For use with them, corrosion resistant flexible tubing. Advantageous for instrumentation of chemical plants, process industries. Can be assembled by hand.

46 Vacuum Pumps. From F. J. Stokes, "The Story of the Ring-Jet Pump" tells why these units were developed. Pumping speeds increased from 10 to 100% above conventional diffusion & booster pumps of same size & heat input. Bridge the gap between 10 & 500 microns efficiently.

48 Wire Mesh Separators. Bulletin on mist eliminators & entrainment separators from Otto H. York Co., Inc. explains how knitted units effect clean separation between liquid & vapor in vacuum towers & other apparatus. Efficiency exceeds 99.9%. Fabricated in variety of materials.

49 Turbo Dryer. Wyssmont Co. vertical continuous transfer type Turbo-Dryer described in bulletin detailing engineering characteristics, advantages, areas of usefulness.

52 Mixers. New illustrated catalog from Read Standard Corp. on spiral ribbon mixers of from 1 to 500 cu.ft. Temperatures & pressures in capacities 1 qt. to 1,500 gal.

54 Gate Valves. For special use in corrosive service Lunkenheimer "Casual" metal gate valves. Sizes ½ to 8 in. with screwed or flanged ends. Two available trims—18-8 Mo stainless steel or Monel metal. Dimension & application tables given in folder.

55 Mechanical Seals. External rotating mechanical seals for pumps and agitator shafts are subject of catalog from United States Gasket Co. Recommended for handling acids, alcohols, alkalies under rigid chemical service conditions.

56 High Pressure Equipment. Valves, tubes & fittings for use under high pressures & manufactured by High Pressure Equipment Co., Inc. are illustrated in catalog. Cutaway views, details on each item.

57 Flexible Metal Hose. Designed for use by maintenance & purchasing departments new bulletin on corrugated flexible metal hose of both annular & helical construction.

59 Proportional Control. Electric proportional controllers for control of dew point, pressure, temperature, etc. in batch process, combustion atmosphere & heat treating furnace applications. Foxboro Co.

60 Spectrophotometer. From Beckman Instruments, Inc. two new reports on how spectrophotometry solves the metals analyses problem.

61 Load Yield Charts. Crawford Fitting Co. have issued a series of charts showing variation of load at yield of type 304 stainless steel tubing when held by their Swagelok tube fittings.

62 Forged Steel Valves. Small forged steel valves of all types are subject of bulletin from Edwards Valves, Inc. Sizes 2½ in. & under. Stainless steel stem & hard surfaced seat & disk reduce maintenance requirements.

63 V-Belt Drives. A 74-page selection booklet replete with handy multi-color tables for easy selection of Texrope V-belt drives is released by Allis-Chalmers Mfg. Co. Includes information on design features, basic drive principles & technical data.

65 Pyrometer Control. Bulletin from Barber-Colman Co. gives service tips on use of pyrometers. Convenient reference material for instrument men printed on binder insert sheets.

66 Two-Stage Pumps. Allis-Chalmers two-stage pumps for boiler feed & other high pressure applications are described in a new bulletin. Available in close-coupled & frame-type construction in capacities to 300 gal./min. at heads of 300 to 550 ft., temperatures to 250° F.

68 Strip-Chart Recorders. Bristol Co.'s line of 6 in. stripchart recorders for pressure, liquid level, temperature, & flow illustrated in bulletin. Shows methods of applying instruments to variables. Use of instrument as receiver for remotely generated signals, either pneumatic or electrical, described.

69 Process Pumps. Fifteen types of process pumps for the chemical industries are illustrated & described in folder from Byron Jackson Co. Includes uses, construction, capacities, heads & temperatures handled.

70 Gate Valves. Forged steel gate valves said to weigh less & have longer life announced by R-P & C Valve Div., American Chain & Cable Co. Improvements include stainless steel eyebolts, nuts, sturdier gland, follower. Have redesigned stuffing boxes & smooth operating stem, which cannot damage packing during assembly.

equipment-

79 Freeze-Drying Units. Three new types from Naresco Equipment Corp. Though designed for varying uses all have reliable, rugged, direct-reading gauges, & pumps which maintain efficiency even when pumping 100% water vapor. For use in drying penicillin & blood plasma, etc. Data sheet on each unit.

81 High Pressure Pumps. Philadelphia Pump & Machinery Co. have developed a series of high pressure, reciprocating plunger pumps for pressures to 50,000 lb./sq.in.

83 Electronic Process Control. An all-electronic controller designed for mounting on a standard radio relay rack is available with prefabricated cable for connection to any Manning, Maxwell & Moore electronic process control system.

84 Electronic Scanning Instrument. Check & control of various steps in production processes made simple by use of electronic scanning instrument from Robertshaw-Fulton Co. Monitors variables such as temperature, level, flow & pressure. Untrained personnel can set all 25 control points in minutes.

85 Radiation Detector. Said to be five times more rapid than existing models, a high-speed radiation detector from Minneapolis-Honeywell Regulator Co. Responds to 98% of any temperature change in less than ½ sec. Three models.

87 Roto-Bin-Dicator. A paddle-type bin level indicator for special installations introduced by Bin-Dicator Co. Especially adaptable to use in bins under vacuum or pressure; units handling materials containing large lumps tending to bridge over a diaphragm; or materials tending to prevent operation of diaphragm. Bulletin.

93 Positive Displacement Pump. Eco Engineering Co. All-Chem stainless steel positive displacement process pump is now available in type 20 alloy & Hastelloy C for rigid service with corrosives in chemical production, laboratory & pilot plant.

94 Deflection Indicator. For use on equipment requiring prompt detection of relative motion a deflection indicator from Allis-Chalmers Mfg. Co. Device is adaptable to any shafted machinery including marine engines, sewage, irrigation & pipeline pumps & compressors. Time delay prevents false warnings.

95 Control Valve. Known as type 10 valve converts from pressure reducing & regulating to back pressure control by switch of control line described in bulletin from A. W. Cash Co. Recommended for air, water, light oils, gases, refrigerants. Bulletin shows schematic diagram lists other valves in the series.

96 Turbine Pump. Especially designed for cold process applications & handling liquid ammonia, liquified petroleum gases, & chemicals a turbine pump from New York Air Brake Co. Packing box replaced by mechanical seal subject to suction pressure only.

97 Rotary Mechanical Seals. For specific use in high temperature (hot sealing) service two types of Dura seals for balanced & unbalanced assemblies. Constructed of stainless steel, wearing faces equipped with stainless steel U ring shaft packings. Bulletin. Durametallic Corp.

99 Heat Exchangers. Called Inner-Fin & developed by Bush Mfg. Co. unit is said to be a new concept in heat transfer engineering. Applicable wherever heat transfer is required. Bulletin gives engineering data.

INDUSTRIAL REACTOR —SEVEN COMPANIES JOIN

Seven leading process industry firms join to build, own and operate a nuclear research reactor.

First nuclear reactor to be owned and operated by private industry for research in industrial and humanitarian fields, to be built somewhere near New York, is in the planning stage, will go into construction this fall.

Eight companies are involved in the project at present: AMF Atomics, Inc., a subsidiary of American Machine and Foundry, which will build the reactor, Chas. Pfizer, International Nickel, U. S. Rubber, Socony Mobil, Corning Glass, Continental Can, and American Tobacco.

Cost is estimated between $1.5 million and $2 million, final selection of site is subject to AEC clearance since the reactor's fissionable fuel will be obtained on a lease basis. Called Industrial Reactor Laboratories, the new project will be operated by a leading university, policy will be set by a Board of Directors made up of representatives of each company involved.

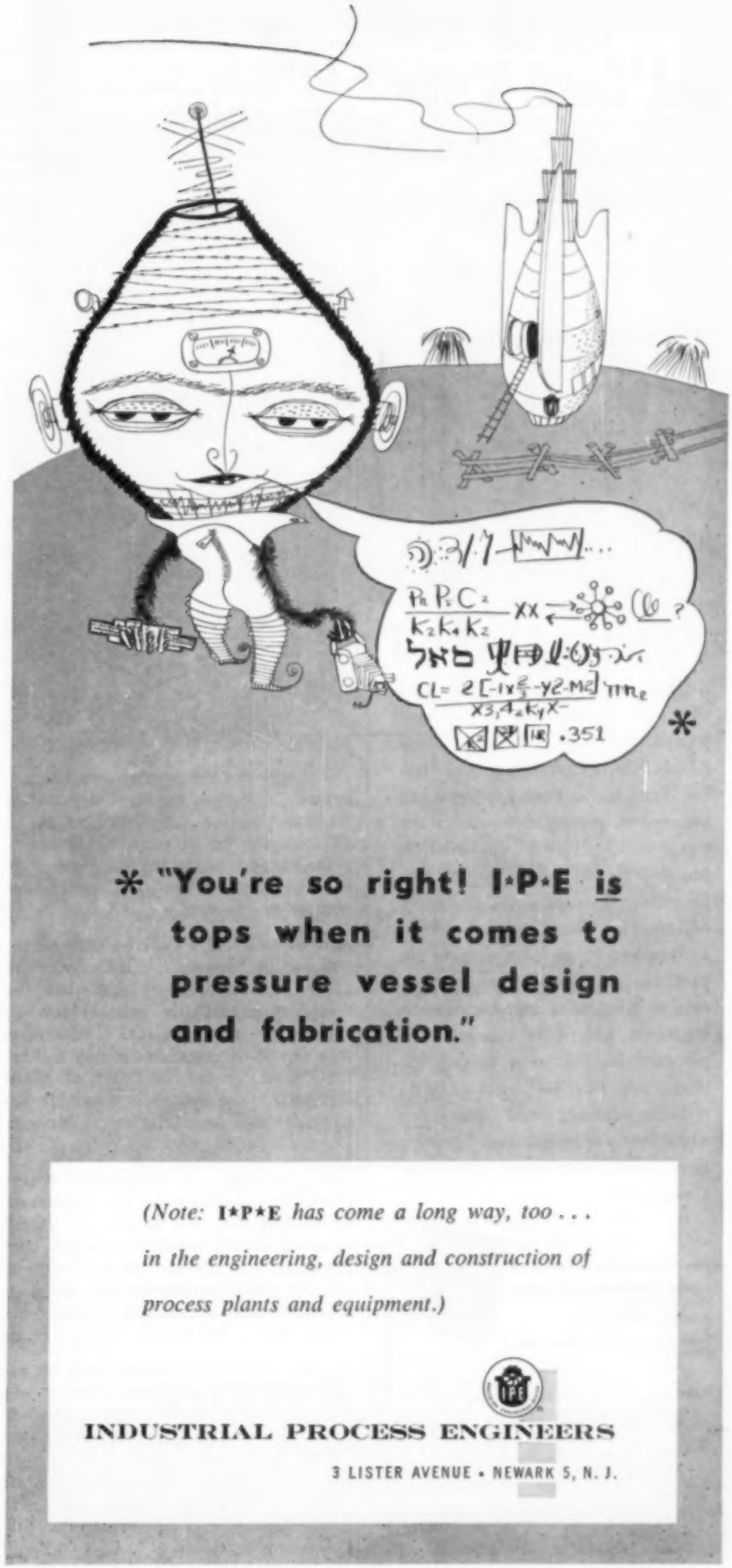
The reactor itself will be of the "swimming pool" type, using uranium fuel surrounded by water as moderator, coolant, and shield.

The companies expect great value from the research done by the reactor on every possible phase of nuclear utilization, including the production of tracer-isotopes for medical use, radiation studies as they affect food, drugs, chemicals, metals, petroleum products, and many other important applications.

Certainly this reactor is a major step forward in the peaceful development of industrial energy in this country. □

Vulcanization of rubber with high-intensity gamma radiation has produced elastomers with markedly better resistance to dry heat and oil aging than chemical vulcanization. This report on the new vulcanization technique, detailed and filled with remarkable possibilities, is contained in an Air Force study available from the Office of Technical Services, Dept. of Commerce. □

Volume production of "Master Slave Manipulators," devices for handling radioactive materials in nuclear research while remaining protected, is bringing about a considerable reduction in the prices of these highly important tools. Previously custom-made, the new "stock" manipulators of AMF Atomics, Inc., a subsidiary of American Machine & Foundry, mark still another step toward full commercialization of nuclear energy. □


* "You're so right! I·P·E is tops when it comes to pressure vessel design and fabrication."
(Note: I·P·E has come a long way, too . . . in the engineering, design and construction of process plants and equipment.)
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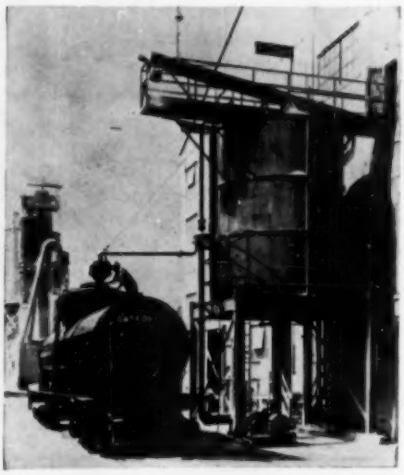
INDUSTRIAL NEWS

The problem of loading and unloading magnesium hydroxide has been solved by Kaiser Aluminum and Chemical Corporation by the use of a Kinney Heliquad pump. In a way the solution was accidental. It was found that the pump unexpectedly homogenized the highly viscous chemical, making it flow more freely, load evenly, and refrain from separating during transit so that unloading was vastly simplified.



The old method necessitated loading, bumping the tank car to distribute the material, loading again, etc., et al. It all took the better part of 48 hours. With the new pump, loading time of an 8,000-gallon tank car has actually been reduced to 75 minutes. □

A mathematically derived method for measuring thermal conductivity of gases, independent of radiation and therefore particularly suitable for use at elevated temperatures, is described in a report of research done by Columbia University for the Office of Naval Research. The report is available for $1 from the Office of Technical Services, Dept. of Commerce. □

For designers of equipment where thermal expansion is an important factor, the National Bureau of Standards has come up with research confirmation that the thermal expansion of certain cobalt-iron-chromium alloys is extremely low and nearly constant between 20° C. and 60° C. □

A new computing center will be established in Westchester County just outside New York City by the Nuclear Development Corporation of America.

Designed to fill the company's own needs for computing machinery in its reactor design and development program, the Center will also be available to other companies. □

HART-CARTER TO EXHIBIT AT CHEMICAL SHOW

Visit Booth C-18 at the 25th Exposition of Chemical Industries in Philadelphia, December 5-9. You'll see standard operating models of Hart-Carter equipment which will demonstrate how the various types of machines size and separate free-flowing granular materials.

Get the facts about ACCURATE SIZING of granular materials

Hart-Carter machines size or separate by dimensional differences —that is, by length or by width or by thickness. These machines use (1) pocketed Carter discs or (2) indented Hart Uni-Flow cylinders or (3) Carter Precision Grader cylinders perforated with either slots or round recessed holes.

IN THE MEANTIME—

Two folders describe the principles and methods used in Hart-Carter equipment. One folder —L-1—discusses length separation. The other—CPG-2—describes sizing or separating by width or thickness. Write for these folders today.

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669 19th Ave. N.E.
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MACHINERY FOR CLEANING AND SIZING GRAIN, SEED, AND OTHER GRANULAR MATERIALS

A unique thrift plan has been instituted by Du Pont, more than 64,000 employees have already signed up. Basically designed to encourage purchase of U. S. Savings Bonds and Du Pont Common Stock, the plan consists of Du Pont contributing 25 cents of its own money to the employee for every $1 he saves. The Du Pont money is then used to purchase the company's Common Stock for him.

In this way the employee is encouraged to save, and also builds an equity in Du Pont stock, which the company wants. □

A West Coast plant will soon be established by Clark Equipment Company, a leading producer of materials handling and earth-moving equipment. □

A great deal of the credit for confining the disastrous recent fire at Standard of Indiana's Whiting refinery to an area of some 10 acres has been given to the use of two-way radio communications by the heroic fire-fighting personnel of the plant. At the height of the fire the telephone system

was totally incapacitated and the radio equipment, product of Motorola Communications and Electronics Division, assumed the giant task of coordinating the work. □

A new plant for the formulation, packaging and distribution of automotive antifreeze and related products has just been completed by Olin Mathieson Chemical Corporation near Pittsburgh.

Actually built by Penn Glenn Oil Works, Inc., and to be operated by them under long term contract, the site occupies 26 acres, has a terminal tank capacity of 2 million gallons.

Olin Mathieson is a major manufacturer of methanol and ethylene glycol, basic ingredients of the two standard types of automotive antifreeze. □

A new latex compounding plant has just been put into operation by the Naugatuck Chemical Division of U. S. Rubber at Gastonia, N. C. □

2500 POUNDS OF PUMP RUNNER

A TYPICAL DURALOY HIGH ALLOY CASTING

This casting is 18-8, destined for use under quite corrosive conditions. It's typical of the work done in our modern foundry for both manufacturers who need high alloy castings for their equipment and for plant operators who need castings to meet a corrosion problem, a high temperature problem or a combination of both, with or without abrasion as a contributing factor.

We here at Duraloy now offer several distinctly different kinds of castings, all in the corrosion-resisting, heat-resisting or abrasion-resisting class and each kind offering certain distinct advantages:

static sand castings
centrifugal castings
shell molded castings

Shell molding offers great economy in the casting of small pieces on a large mass production basis.

Bring your high alloy casting problem to Duraloy both for recommendations as to the best alloying combination and for foundry services in casting and finishing the piece. Our recommendations and service are backed up by more than thirty years high alloy casting experience.

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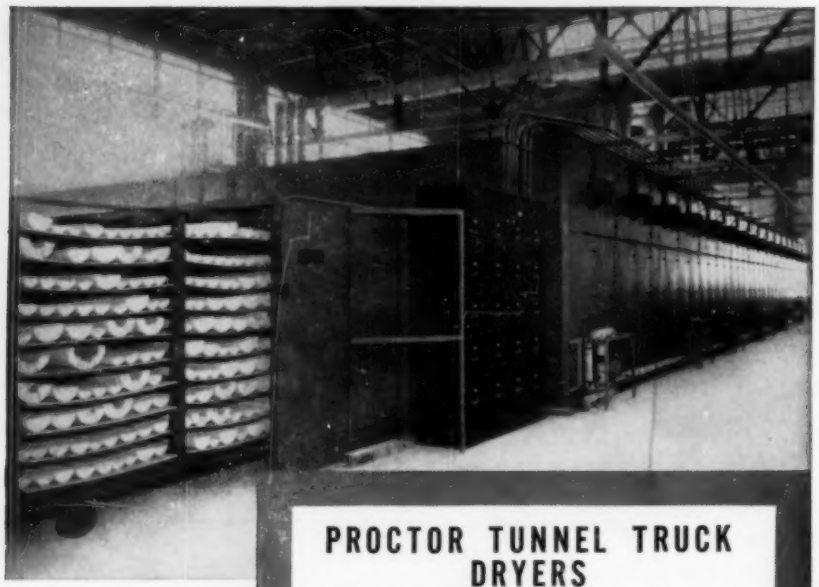

Proctor Tunnel Truck Dryer for molded insulation. Highly effective for handling materials not suitable for drying in a conveyor type dryer.

PROCTOR TUNNEL TRUCK DRYERS

- **Flexibility of Operation**
- **Unitized ⅌ Construction**
- **Quicker Erection**
- **Improved Air Circulation**
- **Easily Expanded**

Proctor Tunnel Truck Dryers have long been standard in the chemical and process industries for efficient, continuous drying of materials, which by their size, density, or composition require prolonged drying times or conditioning periods. Now an entirely new type of housing construction offers added advantages in terms of speed of erection and smoother, easier-to-clean interiors. Latest temperature, humidity, and air circulation controls assure flexibility of operation, while improvements in the air circulation system result in new uniformity of air distribution, and better drying.

Proctor engineers are backed by a record of more successful drying installations than any other company in the world . . . they will be glad to recommend equipment best suited to your needs.

Write for information bulletins on the following Proctor Drying Equipment

- Tray Dryers
- Truck Dryers
- Pre-forming Feeds
- Continuous Conveyor Systems
- Spray Dryers

Proctor

PROCTOR & SCHWARTZ, Inc.

Manufacturers of Industrial Drying Equipment and Textile Machinery • Philadelphia 20, Pa.

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before November 15, 1955, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Anderson, Harvey L., *St. Paul, Minn.*
Bakes, Stanley E., *Aiken, S. C.*
Bishop, Truman B., *Midland, Mich.*
Brugmann, Elmer W., *Wilmington, Del.*
Bucherer, Walter Frederic, *Yardville, N. J.*
Chernosky, Anthony J., *Union, N. J.*
Fillmore, William W., *New York, N. Y.*
Haas, Harold W., *Phillips, Tex.*
Holle, Norbert G. T., *Westport, Conn.*
Holloway, Paul W., *Philadelphia, Pa.*
Houston, Jacques B., *Baton Rouge, La.*
Huggins, John C., *San Mateo, Calif.*
Jarman, Gordon N., *Baltimore, Md.*
Jastrzebski, Z. D., *Easton, Pa.*
Jost, Jacob M., *Cleveland, Ohio*
Kettenring, Kenneth N., *West Chester, Pa.*
Lamb, W. P., *New York, N. Y.*
Levey, Ralph P., Jr., *Oak Ridge, Tenn.*
Mackay, Robert H., *Cheyney, Pa.*
Malley, Thomas J., *Stamford, Conn.*
Mason, David Malcolm, *Glendale, Calif.*
Mongan, E. L., Jr., *Louisville, Ky.*
Oberg, G. Carroll, *Richland, Wash.*
Palermo, Joseph A., *Clark Township, N. J.*
Ramer, Marvin M., *Pittsburgh, Pa.*
Redding, E. D., *Houston, Tex.*
Rogers, Julian A., *Memphis, Tenn.*
Skaggs, Jack A., *Freeport, Tex.*
Spielman, Maurice, *Haifa, Israel*
Taylor, L. S., *Lake Jackson, Tex.*
Thompson, Bert J., *Tulsa, Okla.*
Vera, Arturo, Jr., *Hato Rey, Puerto Rico*
Wan, S. W., *New York, N. Y.*
Wise, Harold F., *Springhill, Ala.*
Wood, F. T., Jr., *Los Angeles, Calif.*
Zahn, Willard R., *York, Pa.*

Associate

Avery, William F., *Columbus, Ohio*
Bakaitis, Algis R., *Chicago, Ill.*
Becker, Hugo G., *Woodbury, N. J.*
Brant, Victor L., *Tulsa, Okla.*
Carney, H. C., Jr., *San Marino, Calif.*
Carter, William D., *Kingsport, Tenn.*
Converse, Alvin O., *Norwood, Pa.*
Crecca, John D., Jr., *Charleston, W. Va.*
Dacey, Raymond B., *Brooklyn, N. Y.*
Davila, S. Garza, *Nueva Rosita, Coah, Mexico*
Drexler, Thomas, *Pittsburgh, Pa.*
Dunlop, Roland H., *East Longmeadow, Mass.*
Erdmann, R. E., Jr., *Matawan, N. J.*
Ewart, John A., Jr., *Holland, Mich.*

Fala, Anthony L., *Ardmore, Pa.*
Foecking, Ralph M., *Fairview Park, Ohio*
Gammon, William H., *Ashland, Ky.*
Gazzillo, Ralph A., *Ridgefield, N. J.*
Gingrich, James E., *Wenatchee, Wash.*
Greenfield, Harold H., *Richland, Wash.*
Gregory, D. W., *Texas City, Tex.*
Gutoff, Edgar B., *Berlin, N. H.*
Heffelbower, Dwight E., *Burlington, Iowa*
Heuser, A. Stanley, *Rochester, N. Y.*
Holstein, Edward D., *Tulsa, Okla.*
Ikeda, Otto M., *Chicago, Ill.*
Johnson, Richard C., *Albany, N. Y.*
Johnson, Robert C., *So. St. Paul, Minn.*
Jones, Fred E., *Edgewood, Md.*
Karn, William S., *East Hartford, Conn.*
Kendall, H. Benne, *Cleveland, Ohio*
Laity, David S., *Fairfield, Conn.*
Lampard, Robert W., *Somerville, N. J.*
Lind, Thomas R., *Naugatuck, Conn.*
Loureiro, Valentin R., *Plainfield, N. J.*
Lovell, Robert L., *Verona, Pa.*
Lucas, Robert L., *Newark, Del.*
Lyda, Carl B., Jr., *Austin, Tex.*
Mader, Frederick W., *Wilmington, Del.*
Martin, Jack W., *Martinez, Calif.*
Meader, John W., *Edgewood, Md.*
Michellepis, C. P., *Alexandria, Egypt*
Mikesell, Ritchie D., *Terre Haute, Ind.*
Mitchell, William W., *Westfork, Ark.*
Moskovits, Peter D., *Bessemer City, N. C.*
Nelson, James R., *Barberton, Ohio*
Oliver, Raymond A., *San Saba, Tex.*
Overton, William O., *Montgomery, Ala.*
Pierce, R. Dean, *Akron, Ohio*
Pigott, George M., *Seattle, Wash.*
Potts, Bobby C., *Midland, Mich.*
Printz, Philip J., *Reading, Pa.*
Ridenour, Dart L., *Oakmont, Pa.*
Roberts, J. Sydney, *Whittier, Calif.*
Robinson, George P., *Wilmington, Del.*
Rogers, Edward A., *Baton Rouge, La.*
Schneider, F. H., *La Marque, Tex.*
Shannahan, F. M., *Baton Rouge, La.*
Smith, William J., Jr., *Pittsburgh, Pa.*
Sol, Enrique A., *El Salvador, C. A.*
Stephan, Robert W., *Pittsburgh, Pa.*
Thomas, David S., *El Dorado, Ark.*
Unger, Edward W., Jr., *Houston, Tex.*
Van Meter, Donald L., *Sherman, Tex.*
Voytko, John D., *Johnstown, Pa.*
Woodle, Hughey A., Jr., *Christiansburg, Va.*
Yorizane, Masahiro, *Hiroshima, Japan*

Affiliate

Kaljo, Gvido, *New Rochelle, N. Y.*
Oetiker, Niklaus K., *Edgecumbe, New Zealand*
Richards, James C., *Edgewood, Md.*

A 25-minute color motion picture, believed to be the first sponsored by one of the major engineering societies, is being distributed free of charge throughout the country by the A.S.M.E. Titled "To Enrich Mankind," the film is designed to explain to the public the significance of the role mechanical engineering plays in the development of the country. □

POSEY pressure vessels are in active service in most civilized parts of the globe. These twin tanks were designed for propane storage for a South American industry. Fabricated from 1" steel plate, each tank is 34' long and 10' in diameter, and operates at pressures up to 250 lbs. per square inch.

Posey Iron has over 45 years experience in the design, fabrication and erection of pressure vessels . . . large and small sizes . . in steel and alloy steels . . for both liquids and gases. All equipment is tested to considerable excess over normal working pressures. All standard codes are met, including ASME and API-ASME.

Let Posey Iron quote on your next pressure vessel job. Prices and specifications furnished upon request without obligation.

Elevated Tanks • Horizontal Tanks • Stacks
Pressure Vessels • Digesters
Carbon Steel and Alloy Steel Plate Fabrication
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POSEY IRON WORKS, INC.
Steel Plate Division
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NEWS from FILTERTOWN

Extremely versatile E&D #613 is equally at home in the laboratory and the industrial plant.

In the former, it is used for analysis of blood to determine sugar content, for hospital analysis tests and as indicator papers.

In the latter, it is used for filtration of such widely diversified products as fruit juices, colognes, drugs, medicinal oils, pharmaceuticals, salt solutions and bees wax.

The physical characteristics of grade #613 are: .006 inches thick, smooth surface, rapidity 60, wet strength 4.8.

We, however, are the very first to admit the likelihood that it does some jobs better than others. And by better, we think in terms of clarity of filtrate, rapidity and economy.

Thus, we continually stress the advisability of permitting our know-how to help you select the right grade of filter paper for your particular filtration process—or product.

Since E&D has sixty-five years of experience and research tucked away, and since E&D is the only company in America exclusively devoted to the manufacture of filter paper, there's a more than reasonable chance that we can be of help to you.

Write for free samples.

And ask for our Filtration Analysis Report if you have any doubts about whether you're using the right filter paper. No obligation, at all.

E&D The EATON-DIKEMAN Co. FILTERTOWN (R) MT. HOLLY SPRINGS, PENNA.

FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

■ **ANNUAL—DETROIT, MICH.**
Nov. 27-30, 1955. Statler Hotel.
Program appears on page 59 of this issue.

■ **LOS ANGELES, CALIF.**
Feb. 26-29, 1956. Statler Hotel.
TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

New Techniques for Utilization of Fast Reactions & Freezing of Equilibria
CHAIRMAN: W. H. Corcoran, Cal. Inst. of Tech., 1201 E. Cal. St., Pasadena, Calif.

Current Status of the Completely Automatic Process Unit
CHAIRMAN: F. C. Brunner, C. F. Braun & Co., 1000 S. Fremont Ave., Alhambra, Calif.

Supervision of Technical Personnel (Panel)
CHAIRMAN: R. D. Gray, Cal. Inst. of Tech., 1201 E. Cal. St., Pasadena, Calif.

Air Pollution
CHAIRMAN: H. P. Munger, Syracuse Univ., Syracuse 10, N. Y.

ABC's of Machine Computation
CHAIRMAN: R. C. Johnson, Dept. of Chem. Eng., Wash. U., St. Louis 5, Mo.
Deadline Past

■ **NEW ORLEANS, LA.**
May 6-9, 1956
TECHNICAL PROGRAM CHAIRMAN: H. E. O'Connell, Assoc. Dir. Process Div., Sect., Ethyl Corp., Box 341, Baton Rouge, La.

Fundamental Mechanism in Boiling, Cavitation and Condensation
CHAIRMAN: R. R. Hughes, Shell Dev. Co., Emeryville, Calif.

Foreign Chemical Developments & their Effect on U. S. Chemical Industry
CHAIRMAN: C. W. Humphreys, Shell Chem. Corp. 50 W. 50th St., New York, N. Y.

Liquid Metals
CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., N. Y 17, N. Y.

Fluid Mechanics
CHAIRMAN: Harold Johnson, Dept. of Mech. Eng., U. of Calif., Berkeley.

■ **PITTSBURGH, PA.**
Sept. 9-12, 1956
TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

Mixing
CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Purdue U., Lafayette, Ind.

■ **ANNUAL—BOSTON, MASS.**
Dec. 9-12, 1956. Hotel Statler.
TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.
Deadline—August 9, 1956

■ **WHITE SULPHUR SPRINGS, W. VA.**
Mar. 13-19, 1957. The Greenbrier

MEETINGS **SYMPOSIA**

■ **SEATTLE, WASH.**
June 9-12, 1957. Olympic Hotel

■ **BALTIMORE, MD.**
Sept. 15-18, 1957. Lord Baltimore

■ **ANNUAL—CHICAGO ILL.**
Dec. 8-11, 1957. Conrad Hilton

UNSCHEDULED SYMPOSIA

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases
CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Distillation Computation Methods
CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

Operations Research
CHAIRMAN: George D. Creelman, Creelman Assoc., 2245 Harcourt Dr., Cleve., O.

Filtration
CHAIRMAN: F. M. Tiller, Dept. of Eng., U. of Houston, Cullen Boulevard, Houston 4, Tex.

■ **CLEVELAND, OHIO**
Dec. 12-17, 1955. Cleveland Auditorium.
Program appears on page 70 of this issue.

LOCAL SECTION future meetings

■ **NEW YORK**
Nov. 15, 1955
Joint meeting with Instruments and Controls Section, Metropolitan section, A.S.M.E. on **"Electronic vs. Pneumatic Controls."**

■ **NEW HAVEN**
Nov. 22, 1955
C. Ivy Smith, Jr., **"Titanium."**

■ **PITTSBURGH**
November meeting
Plant trip to be arranged.

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. F. J. Van Antwerpen, American Institute of Chemical Engineers, 25 West 45th Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the bottom of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. J. B. Mellecker, 25 West 45th Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E. at 25 West 45th Street, New York, a copy of the A.I.Ch.E. Guide which covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The three other copies should be sent to J. B. Mellecker, Editor of C.E.P., 25 W. 45, N. Y. 36, N. Y. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

Chairman, A.I.Ch.E. Program Committee, George Armistead, Jr., George Armistead & Co., 1200 18th St., N.W., Washington, D. C.

Assistant Chairman, L. J. Coulthurst, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

A new, triple-powered electron beam generator is being developed by the X-Ray Department of General Electric. Intended for the production of improved chemical products, such as irradiated polyethylene, as well as the sterilization of foods and drugs, the new machine will undoubtedly find quick application.

The presently-under-development machine will operate at 2 million volts, will provide twice the penetrating power of older machines. Older machines already in use have proven highly successful.

At one new installation, Michigan State College, where a million-volt machine has just been installed, advanced research on the machine's insect and bacteria killing properties is under way. □

A new radiochemistry laboratory for use in preparing and distributing standard samples of radioactive materials has been established at the National Bureau of Standards. This is the sixth facility provided by NBS to furnish radioactive standards required by the medical, scientific, and commercial users of radioactive materials. □

New sales representative for Vanton Pump & Equipment Corp. is Unit Process Co., Seattle, Wash. Territory will be Idaho, Montana, Washington, Oregon and Alaska. □

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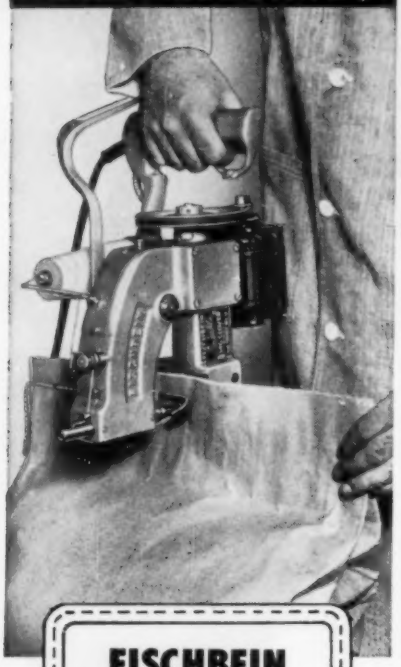

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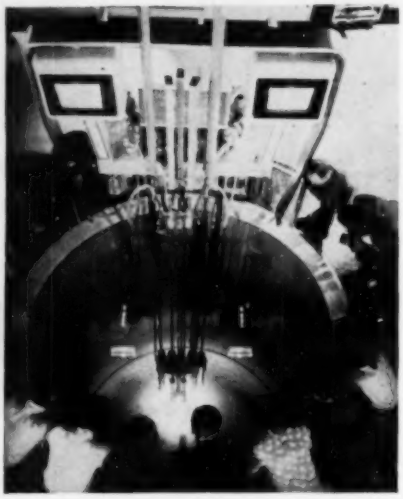
NUCLEAR NEWS



First full-scale atomic reactor was shown to the public as part of the U. S. exhibit at Geneva. Designed and built at Oak Ridge by Union Carbide and Carbon, the reactor was of the swimming pool type. After the close of the Geneva Conference the reactor was turned over to the Swiss for use in research work.

A major impetus to AEC's giving up its cyclotron-produced radioisotopes program is the emergence of a private commercial firm, Nuclear Science and Engineering Corporation, to do the job.

NSEC has available, and offers for sale, a long list of accelerator-produced isotopes. It maintains stocks of the more commonly used materials, will produce on request almost any radioisotope which can be produced in a cyclotron or synchrocyclotron. Even short-lived isotopes will be specially shipped if requested.

AEC authorization is not required, and consultation on proper use and handling is offered. □

First full-fledged peacetime atomic energy exposition to be held in New York will run from October 20 through November 3 at the Carnegie Endowment International Center.

Sponsored jointly by Atomic Industrial Forum, Fund for Peaceful Atomic Development, and the Carnegie Endowment for International Peace, it will stress uses for advancement of human welfare, will draw many exhibitors from the already-held U. S. Trade Fair of the Atomic Industry at Washington, plus many foreign exhibitors. □

An "Introduction to Nuclear Power Plant Engineering" will be given this semester by Stevens Institute of Technology, Hoboken, N. J. A non-mathematical course, it will consider the general engineering problems involved. □

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With the rapid expansion of the field of nuclear science, various needs have developed for ionXchange, particularly in the purification of wastes contaminated by radioactivity. ILLCO-WAY equipment has been designed and built for this and other purposes in several plants employing atomic energy. *For further information on the uses of ILLCO-WAY ionXchange, write . . .*

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NUCLEAR NEWS

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Conferences designed to help in the increased use of science fairs as educational tools for the advancement of science, are being arranged by Oak Ridge Institute of Nuclear Studies in cooperation with state academies of science. Presently scheduled conferences are at Jackson's Mill, Weston, W. Va., on October 30-November 1, and at North Carolina State Agricultural and Technical College, November 18-19. Three others have already been held. □

A nuclear scanning device is regulating the quality of every foot of Hudson Pulp & Paper's kraft paper produced at its Palatka, Fla., mill.

The largest unit of its type ever installed in a kraft paper mill, the scanner sweeps back and forth across the paper-making machine and its beta rays measure the precise weight of the paper, an electronic integrator automatically regulates and controls the flow of pulp fed to the machine.

It is expected that a basis weight with a variance of less than 2% will be secured, compared to the commercially acceptable 5%. Result: Greater uniformity, greater strength. □

Industrial users of radio-isotopes now outnumber medical users. The rapidly growing importance of radio-isotopes, to be studied in a two-week course at Purdue Univ. starting July 25, has plunged industry deep into the atomic age, with 1200 users of radio-isotopes in industry already. □

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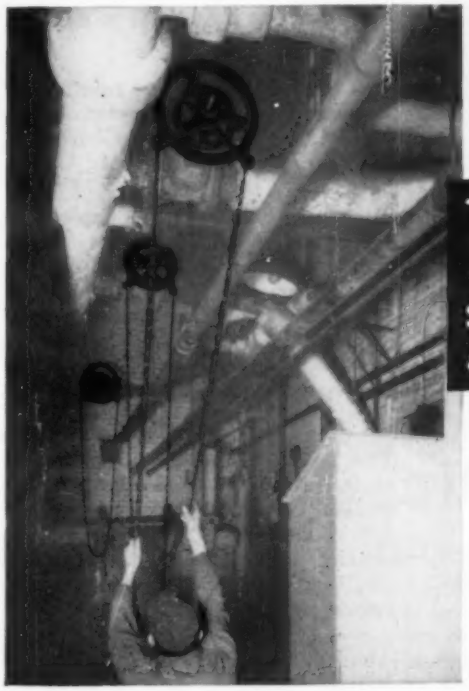
Cleveland, Dec. 12-16



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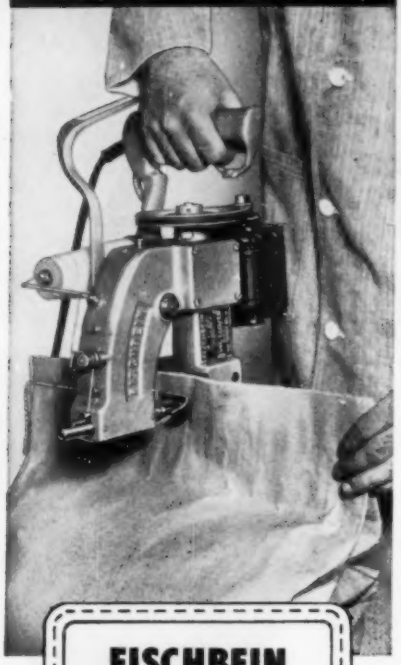

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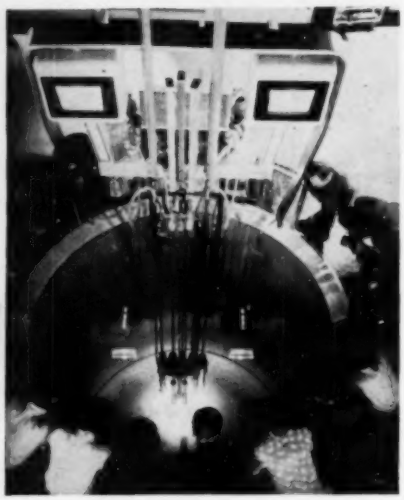
NUCLEAR NEWS



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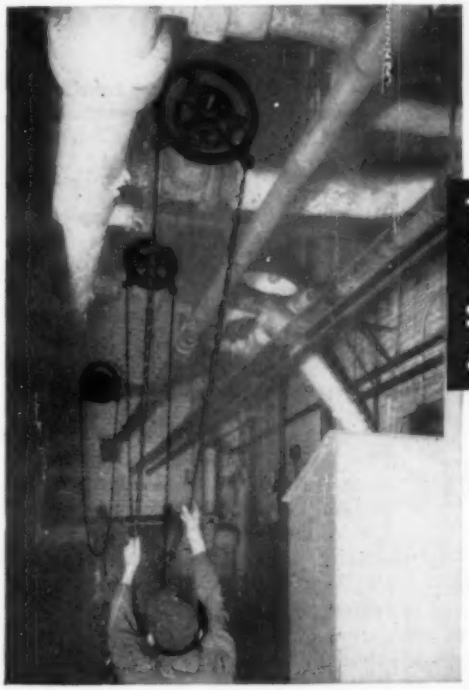

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ALL EYES ON BUBBLES

—AND ON R. C. KINTNER

A national magazine features Illinois Tech's R. C. Kintner and his long-time work on the mechanics of bubbles and drops.

A high-spot of the up-coming Detroit Annual Meeting will be two symposia on the mechanics of bubbles and drops. Driving force behind the interest in this field is R. C. Kintner, Professor of Chemical Engineering at Illinois Institute of Technology.

Kintner, systematically studying bubbles and drops since 1949, recently received recognition from *Life* magazine. The wide-circulation picture weekly showed Kintner hard at work on his experiments, showed detailed studies of bubble formation, pointed out commercial importance of Kintner's work.

In Kintner's own view, his work can have far-reaching effects on the more economic production of many chemical products where bubble and drop mechanics are of fundamental importance. Such products as rocket and aviation fuels, oxygen, vinegar, rubber, glycerine, beer, rayon, nylon, fertilizers, dyes, and any product dependent on the efficient use of gas-liquid interchange for economic production, will be vitally affected by Kintner's work.

But Kintner's work is more far-reaching than simple short-range commercial significance. As engineers will find out at Detroit, Kintner's work, combined with that of other investigators, is casting serious doubt on many time-honored concepts of bubble and drop mechanics.

Perhaps more important than either *Life's* public interest, is the National Science Foundation's $6,700 grant to Kintner to enable him to continue his work for at least another two years.

An intensive three-day course on Corrosion Problems in the Process Industries will be given in San Francisco beginning November 14. Under the auspices of the University of California in cooperation with the National Association of Corrosion Engineers, Western Regional Division, twelve experts on corrosion problems in the chemical and petroleum industries will lead discussion from 8 to 5 each day at the University Extension Building. □

A one-day school on heat transfer for teachers was conducted on October 15 by A.I.Ch.E. at South Charleston, W. Va. Host was Carbide and Carbon Chemicals.

Designed to bring teachers up to date on the developments and fundamentals of heat transfer, the one-day school at South Charleston concentrated on the basic considerations in the design, specification, and fabrication of heat exchangers, presented and discussed by such specialists as W. W. Baker, D. S. Ullock, and C. H. Gilmour. □

The largest single employer of engineers in the United States is the Federal Government. It accounted for 11% of the 633,000 American engineers working in 1953. More than 8% of all Federal white-collar workers are engineers. □

Too many students, not enough facilities. That is the story at Carnegie Tech where 3500 applicants appeared this year (25% higher than last year) and only 25% can be admitted. With the engineer shortage these young men can be used by industry if they can find somewhere to study! The problem is serious. □

Graduate research fellowships in the fields of chemical engineering, chemistry, and mechanical engineering, to the tune of about $45,000, will be available this year from the Ethyl Corporation through various colleges and universities. Each fellowship provides $1500 for expenses plus an allowance for tuition and fees. □

The Egyptian AEC is to be advised as to the most effective utilization of materials and money for a nation just beginning an atomic-energy program. Advisor will be Ralph T. Overman, chairman of the Special Training Division of Oak Ridge Institute of Nuclear Studies. Overman will also assist in planning an atomic energy training program for Egypt, and consult on the use of a technical library shipped to Egypt by AEC. □

The use of gamma-ray emitters inside an absorptometer to measure the contents of process chemical streams in a plutonium refinery has been developed by General Electric at its Hanford atomic plant. Thus a way has been found to utilize atomic-energy by-products to continuously and automatically analyze the chemical solutions in the process of making the important atomic fuel plutonium.

Briefly, samples of a chemical solution from the stream are automatically pumped to the disk-shaped lucite chamber every few minutes, the chamber is penetrated by rays from a radioisotope, and the more rays absorbed the higher the concentration of dissolved matter. The absorptometer is stable, simple, small, and economical—it should find wide industrial use. □

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CONGRESS PROGRAM

Preliminary programs for the Nuclear Congress are now ready and have been distributed to A.I.Ch.E. members with the Detroit Meeting Program. The Nuclear Congress program contains the titles of papers, names and connections of authors, a preprint order form, and preregistration and hotel-reservation blanks. Nonmembers of the A.I.Ch.E. may obtain copies from the Institute upon request.

UNDER the coordination of the Engineers Joint Council, nuclear scientists and engineers of 24 industrial and scientific groups and engineering societies will convene at the Nuclear Congress in Cleveland for five historic days beginning December 12. They will hear and discuss more than 290 significant papers presented by leading atomic experts on new developments in the application of nuclear energy to industrial and other uses.

Over 45 of these papers will be presented under the sponsorship of the A.I.Ch.E. These papers will deal with subjects of interest to every Chemical Engineer concerned with nuclear energy. In addition, the Congress will give every A.I.Ch.E. member the rare opportunity of meeting and talking with the nation's foremost nuclear authorities in allied fields of engineering.

Make your plans to attend the Nuclear Congress *now* because accommodations will soon be at a premium.

FOR the first time, A.I.Ch.E. members can see the newest and most important product developments in nuclear science under one roof . . . as well as a nuclear reactor in operation right on the floor . . . at the ATOMIC Exposition. Running concurrently with the Nuclear Congress, under the sponsorship of your A.I.Ch.E., this great exposition will have on display the latest products of approximately 100 manufacturers.

The exposition will open Saturday, December 10, two days in advance of the Congress. Here is your best chance to evaluate new products and developments, get the facts first hand on application data, and talk shop with your contemporaries.

Your A.I.Ch.E. membership is your admission ticket, and qualified nonmembers are welcome. Don't miss this great show of nuclear energy in action!

To Those in the Nuclear Field

The Nuclear Engineering Division of the A.I.Ch.E. has been organized by the Institute for exploration of the technical and economic problems of nuclear engineering. The Division is sponsoring technical symposia at the Nuclear Engineering & Science Congress in Cleveland in December, and at the regular meetings of A.I.Ch.E.

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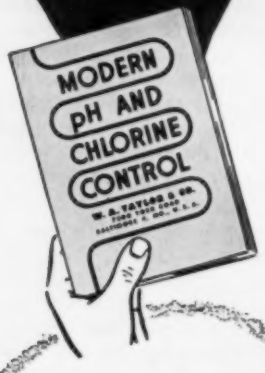

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Gas turbine demonstration courtesy P. L. Ward of Solar Aircraft Co.

A.I.Ch.E. Meeting Sept. 25-28 1955

The ladies do a wee bit of putting around (really, a contest).

Nuclear Engineering Division meeting—F. J. Van Antwerpen, W. K. Davis, J. J. Martin, E. B. Gunyou, R. P. Genereaux.

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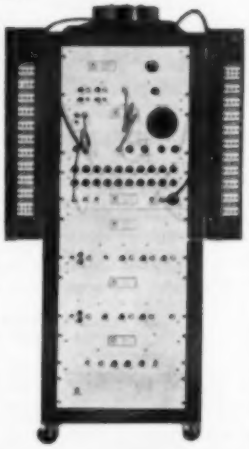

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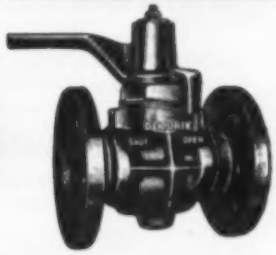

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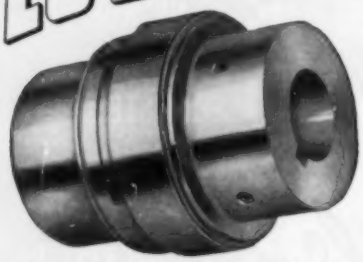

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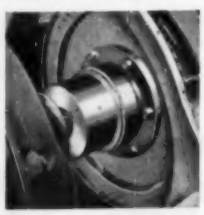

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REPROCESSING EXPANSION

—NUCLEAR FUEL SERVICE

Sylvania integrates its atomic fuel activities as commercial nuclear field grows by leaps and bounds. Key facet is fuel reprocessing.

Sylvania's Atomic Energy Division throws sharp light on the rapidly growing commercial development of peaceful atomic energy.

Sylvania already has an established atomic fuel manufacturing program, is pushing rapidly to add a fuel reprocessing and recovery program. Goal for Sylvania is to provide the reactor and power industries with a complete and integrated fuel and reprocessing service.

Question Mark

As Sylvania sees it, points to many recent AEC statements, the combined problem of spent fuel reprocessing *and* re-fabrication is one of the basic question marks. Until this is licked, economic nuclear power will stay out of reach.

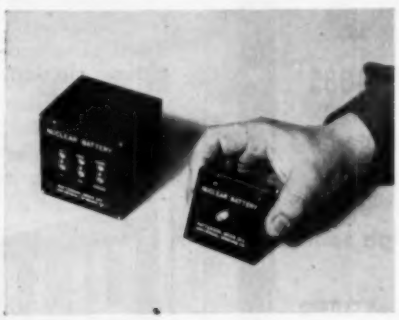
Until recently the entire cycle of fuel manufacture and fuel recovery seems to have been somewhat overlooked in the scramble of a large number of industrial concerns to be first in their field to build a commercial power reactor. But at Lake Placid, at Geneva, at up-coming Cleveland Nuclear Congress, and many other engineers' and scientists' meetings, the problem has come in for sudden and widespread attention. Now Sylvania has made the commercial step toward practical reprocessing.

An important part of the problem is that while major reactor components can be accomplished in existing industrial plants, manufacture and reprocessing of nuclear fuels must take place in a type of facility which is almost non-existent on the American industrial scene.

Nuclear reprocessing means high-cost now, of both investment and operation, but it must be done now in order to gain the operating experience necessary, and to promote enough low-cost power reactors so that volume throughput will begin to work to bring the overall costs down.

Sylvania has been in the field for a long time. But its definite work on reprocessing indicates another fundamental step toward the successful beginning of a commercial nuclear industry.

A nuclear battery that converts atomic energy into electrical energy has now been developed by the Patterson-Moos Research Division of Universal Winding Company.



Energy source is Strontium 90, a by-product of reactor operation, giving the battery an operating life in excess of 25 years, reliable performance from arctic to tropical temperatures. Three models are now available ranging from 1 to 10,000 volts, 5 to 2000 microamperes. Possible applications are many, including: timing circuits, transistor power supplies, control circuits, and others. □

Major tools for the processing of plutonium-containing fuel elements which are essential to the development and operation of fast breeder reactor power plants, are four new 2-high/4-high Combination Rolling Mills currently being built by Stanat Manufacturing Co., Long Island City, N. Y. Costing $150,000, the mills will be installed at Argonne National Laboratory, Lemont, Ill.

Versatile, rugged, and precise, the mills have been adapted for use in conjunction with hoods and remote control handling equipment. □

The new industrial linear atomic accelerator (electron gun) of Atlantic Refining is physical proof of the company's belief that atomic radiation may prove to be the next step in petroleum processing.

With atomic radiation such a promising new tool for refining crude oil, Atlantic went ahead and built the accelerator, which "shoots" atomic particles at velocities up to 600 million miles per hour, hopes to neatly cut petroleum molecules into any desired segments rather than use heat to shatter the molecule, selecting from the "debris" what can be used. □

Non-classified AEC research reports of industrial significance are being made available on a continuing basis by the Dept. of Commerce. This is considered an urgent matter, 961 reports, most never before released, are already available, are free. More will be released as they are available. □

NEW ERTEL PYROGEN & BACTERIAL RETENTIVE FILTERS

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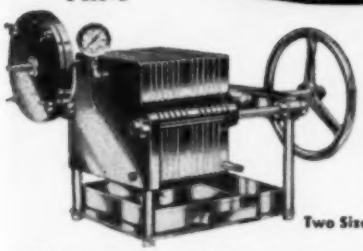

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This most versatile unit is available for either double or single filtration. Double filtration is recommended for critical pyrogen and bacterial retentive work. Available in highly polished stainless steel; can also be furnished in Lucite construction. Lucite is only recommended for applications below 120° F. Compact size makes ESS Models ideal for laboratory or small production use. Model 8 ESS-D accomodates 8" square Ertel Asbestos Filter Sheets, whereas Model 4 ESS-D accomodates 4" square sheets.

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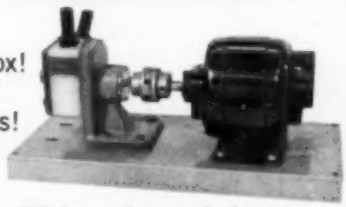

Pumping 65% HF is tough enough, but when service requirements also include 40% H_2SO_4 the problem is really rough. An alert primary metals producer found the answer by replacing two conventional pumps with a Vanton "flex-i-liner" self priming pump and two alternate liners. Model PX60—10 gpm-with a polyethylene body block, a gum rubber liner for the HF and a neoprene liner for the H_2SO_4 did the trick. Two trouble free plastic pumps in one!

When it comes to pumping those tough corrosive liquids and abrasive slurries, there's no pump like a Vanton!

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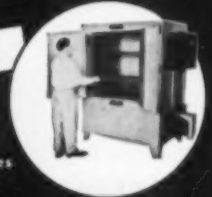

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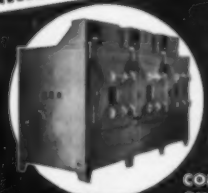

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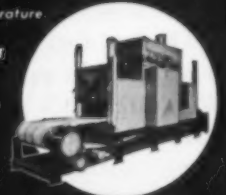

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News of the Field

...a heart too small for breaking

Here is a child's world—balanced on faith, lighted by love, warmed in the safety of a mother's arms, a father's smile. Here is a world of little hearts, all too small for breaking.

What dark shadow could Cancer cast on such a sheltered world? Well, there are some 160,000 children whom Cancer has robbed of their fathers. And more than 175,000 others have had to learn to live without a mother.

Not even the young are safe, for Cancer yearly claims more children from three to fifteen years of age than any other disease.

But there is hope... brave, bright hope. For Cancer *can* be conquered. The vast army led by the American Cancer Society — scientists, doctors, technicians, volunteers — wage daily war on man's cruelest enemy.

You can help conquer cancer. With a *check*—to help others. With an annual medical *checkup*—to help yourself. Remember, every year some 75,000 men, women and children win personal victories over Cancer—and live. One of them might be you—or someone close and dear to you. Will you help? We need you.

American Cancer Society

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☐ Please send me free information about Cancer.
☐ Enclosed is my contribution of $_____ to the Cancer Crusade.

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News of the Field
FROM LOCAL SECTIONS

Dallas, Tex. Engineers must be citizens of their community, and active citizens, as well as scientists. With this idea as keynote, the Dallas Section invited C. F. Hansson, chief of the Dallas Police, to talk on the growth, accomplishments, and problems of the police department at the June 28 meeting.

Later, Paul Bentley, a detective in the department, demonstrated the lie detector for the engineers, giving a vivid example of science's vital spot in modern police work.

—C. J. Holland, Jr.

Augusta, Ga. Mineral resources of the Savannah River region were discussed by L. L. Smith, state geologist of South Carolina, at the May 10 meeting of the Savannah River Section.

—R. W. Hinterleiter

Knoxville, Tenn. A detailed problem in the study of allylic chlorides was the subject of V. L. Tweedie, Baylor University, at the July 26 meeting of the Knoxville-Oak Ridge Section.

Speaking on "Copper (I) Chloride Catalyzed Acid Hydrolysis of Allylic Chlorides Containing Radio-Chlorine," Tweedie pointed out the ambiguous results obtained when the reaction is performed on dichloro compounds because of the uncertainty of the relative extent of reaction of the allylic and the vinylic chlorine atoms. To determine just what did happen, the dichloro compounds were synthesized with chlorine 36 in the allyl position. Isotopic exchange occurred with some 85% of the allylic chlorine remaining as chloride ion in solution.

—R. J. McNamee

Providence, R. I. New officers of the Providence Section are: Morton Port, chairman; A. A. Melnychuk, vice chairman; Ralph Thompson, secretary-treasurer; C. A. Stockel, member executive committee.

—A. A. Melnychuk

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CANDIDATE FOR A.I.Ch.E. OFFICE

Robert E. Zinn

The following picture and brief biography refers to a candidate for director of the A.I.Ch.E. nominated by petition, and received by the Editor too late for inclusion in the July issue of C.E.P.

Professor of chem. engr., Northwestern Univ. (Evanston, Ill.); Partner, Senior chem. eng. Vern E. Alden Co. (Consultants, Chicago, Ill.) Mr. Zinn received much of his industrial experience with Victor Chemical Works, where he served as chief engineer from 1944-51. He has been a chairman and director of the Chicago Section, and has served on its By-Laws Committee, Professional Licensing Committee; and the Institute's Committee on Equipment Testing Procedures (Pumps), and Chemical Engineering Education and Accrediting Committee.

Further details on candidates are available from the Secretary's office. Any member who wishes this biographic data need only request it.

A.I.Ch.E.

News of the Field

FROM LOCAL SECTIONS

SECTIONS RECOGNIZE OUTSTANDING STUDENTS

The New Jersey and Northern California Sections present their Annual awards to outstanding students in their local engineering schools.

Seeking to grant some measure of recognition and encouragement to outstanding engineering students, and at the same time to further the welfare of the whole profession, two local sections, New Jersey and Northern California, hit upon the idea of presenting associate memberships in the Institute as prizes to the most deserving students of the year in chemical engineering.

Presenting its first such awards, the New Jersey Section selected Olev Trass of Princeton, and Lionel Sirois of Newark College of Engineering, the only engineering schools in the state, to be recipients of the certificates of merit, first year's dues as an associate member, and initiation fee.

Northern California, continuing its annual plan, awarded its entrance fee and dues as an associate member, plus an emblem of the national society, to Stanford's John Stetson, and Univ. of California's Philip Anderson.

Prize-winners Sirois, Anderson and Trass.

So far the plans seem beneficial to all: the student is encouraged, his work recognized.

—G. B. Zimmerman
—W. C. Streib

Western New York. Officers of the Western New York Section for 1955-56 are: W. C. Greenwald, chairman; F. A. Cox, vice chairman; W. F. Moore, secretary; D. Altimier, treasurer; T. Hooker, P. W. Reeves, and J. W. Faassen, directors.

—W. F. Moore

Detroit, Mich. Research and development in the field of virus and endocrine research, particularly the development of the anti-polio serum, was the subject of a talk by A. R. Taylor, laboratory director of virology, Parke, Davis, to the September meeting of the Detroit Section.

Basing his talk on Parke, Davis' long research into integrated tissue culture, the work that eventually led to mass-production of the Salk vaccine, Taylor led the engineers through the entire process of this major development.

—Edward Garelis

Southern California. Shale oil reserves in the U. S. are estimated at about 500 billion bbls. compared with a petroleum reserve of 30 billion bbls., G. H. Hemmen, Union Oil, told the July 19 meeting of the Southern California Section.

Shale has been mined and retorted abroad for many years, has been under development by the Government since 1925. Since 1920, Union Oil has been actively developing shale oil as a source of fuel, has recently allocated $5 million for further research and development. A 1000-ton/day unit will be built by Union near Grand Valley, Colo.

Temperature will be 2200° F. in the unit's combustion zone. Heat will be supplied by burning carbon on the shale, condensation takes place on the shale eliminating the need for cooling water. A continuous process, it is expected to yield 90 to 95% laboratory assay.

—F. G. Sawyer

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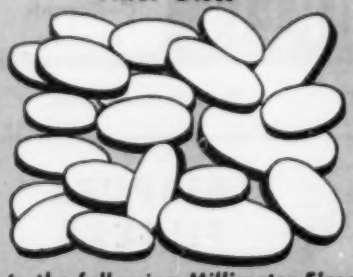

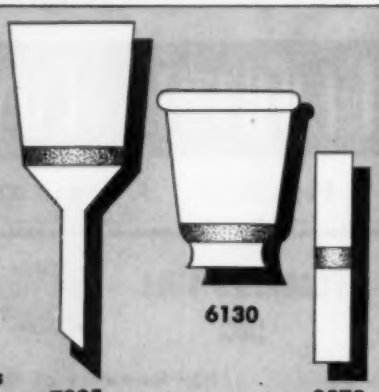

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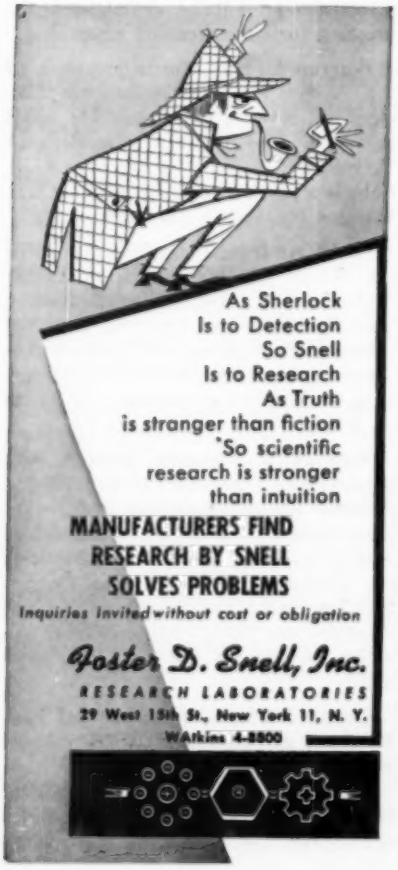

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Boston, Mass. The question of whether or not the Chinese Nationalists could have defeated the Communists by operating at the local level rather than trying to wage a war, provoked lively debate at the April 29 meeting of the Boston Section.

Speaker B. I. Schwartz, Harvard, felt that the local policy might have worked, considered there was no immediate danger of Communist control at that time.

Following its policy of providing "no-shop-talk" sessions for its members, the Boston Section heard Schwartz trace the history of China, emphasizing the twentieth century, explaining the strong foothold secured by the Communists during the Japanese war when their 8th Route Army held the north.

Main cause of Communist victory, according to Schwartz, masses tired of war, little enthusiasm for Nationalist desires to continue attempt to remove Communists that had been going on since 1927.

—W. F. Roemelt

Southern California. The explosive subject of the registration of chemical engineers, particularly hot in California, provoked the liveliest meeting in a long time for the Southern California Section on August 16.

Set up as a panel discussion with Arnold Ames as moderator, B. B. Kuist commenting on the national situation, Ames on the California situation, Harvey Spencer on the advantages of registration, and Ben Holt against registration, the meeting came up with 4 basic reasons for registration, 7 against.

For registration: (1) Aims to protect the public safety, health and welfare. (2) Provides a legal definition and recognition of a professional engineer. (3) Promotes recognition of engineering as a profession. (4) Provides a recognized definition of an engineer which aids exclusion of engineers from unionization.

Against registration: (1) Benefits don't justify $4.00 annual cost. (2) Questionable whether public safety is actually improved or protected by registration. (3) It is doubtful that professional recognition or status is improved by registration, these are a man's personal problem. (4) Examinations for qualifying are a needless complication and duplicate schooling. (5) Engineer-in-training examination and title are of little value. (6) Definitions of various branches of engineering in the law contribute to confusion and weakness in the law. (7) Because State Board is appointed by Governor, registration is tied to politics.

—B. B. Kuist

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monograph

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people

IN MANAGEMENT AND TECHNOLOGY

Robert T. Sheen elected president of Instrument Society of America. Sheen was a founder of the Milton Roy Co., Phila., and is now president of the company. Co-founder also of Chempump Corp., has served as its president since the founding in 1952. As head of I.S.A. Sheen will lead the organization in its continuance in development and use of instruments and controls in industry.

Barnett F. Dodge, A.I.Ch.E. president, is elected an Honorary member of the Institute. Active in A.I.Ch.E. affairs, Dodge has been a full member since 1927. He is chairman of the Dept. of Chemical Engineering at Yale University.

Armour Research Foundation of Illinois Institute of Technology appoints **David H. Kirkeby** asst. manager of heat-power research dept. Part of his responsibility will be development of projects for new areas of research.

Warren L. McCabe is president of the Association of Engineering Colleges of New York State. He holds the position of administrative dean of Polytechnic Institute of Brooklyn. McCabe is a past recipient of the A.I.Ch.E. William H. Walker Award.

R. V. Andrews named new dean of the School of Engineering at Lamar State College of Technology, Beaumont, Tex. He will also head the Dept. of Chemical Engineering at the school. Andrews comes to Lamar from a professorship in chemical engineering at Texas A. & M.

Stewart P. Coleman elected vice-president of Standard Oil Co. (N.J.). Coleman has been a directer of the company since 1946 and had served before that time in government service with the Petroleum Industry War Council and later with the Petroleum Administration for War. He has been an active member of the A.I.Ch.E. since 1932.

Leonard Topper joins staff of Esso Research and Engineering Co. Topper will work in process research div.

John T. Fitzigibbon joins staff of the company assigned to the economics div.

C. A. Stokes elected vice-president and technical director of Texas Butadiene & Chemical Corp. at Houston with headquarters in that city. He is also a director of Petrocarb, Inc., New York. Stokes had served for the past ten years as director of research and development for Godfrey L. Cabot, Inc.

Clark C. Heritage, who has devoted more than 40 years to forest products and chemical developments, retired October 1st as development director for Weyerhaeuser Timber Co. He is one of the nation's foremost figures in pioneering new wood, fiber and bark products. Heritage plans soon after his retirement to open a Tacoma, Wash. office to serve industry in his field.

Ross Brian joins Central Soya Co. in the feed div. as senior chemical engineer in the technical dept. He will headquarter at the Decatur, Ind. plant.

Douglas S. Sherwin returns to Phillips Chemical Co. as asst. coordinator, rubber chemicals div. He had been on loan to the Government as secretary of the Federal Facilities Corp. Sherwin works from the Bartlesville, Okla. office of the company.

Dwight C. Brown transferred to supervisor, chemical engineering service of Jones & Laughlin Steel Corp. The service is a new section in the technical services div.

Rudy Peterson joins American Potash & Chemical Corp. as senior process engineer. He had previously been a chemical engineer with General Petroleum in Calif. Also named is **Karl Wahl** as technician asst. in the company's engineering dept.

Albert H. Cooper, professor of chemical engineering at the U. of Maryland, named chairman of the dept. of chemical engineering at Pratt Institute. Cooper is also manager of the Pilot Engineering Co. and vice-president and technical director of Chemchron Corp.

National Carbide Co. elects **Russell T. Lund** a vice-president. He will continue his headquarters in Calvert City, Ky.

Noel V. Wood, Jr., appointed process engineering supervisor for Mobay Chemical Company. Wood had been serving in Monsanto Chemical Co.'s organic chemicals div.

(*Continued on page* 114)

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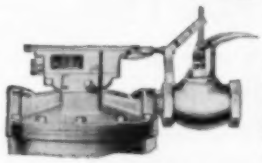

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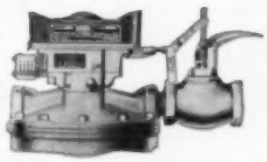

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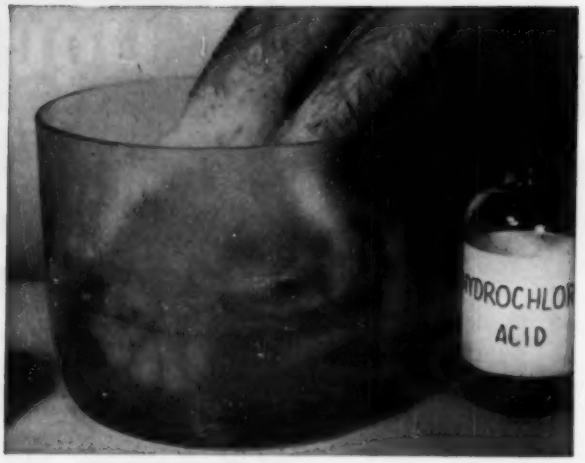

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people

IN MANAGEMENT AND TECHNOLOGY

Donald W. Collier, pictured, and **Charles Howe Goddard** elected vice-presidents of Thomas A. Edison, Inc. With the company since 1951, Collier began as director of product research and will continue also in this capacity.

Lawrence R. Hafstad, leading atomic energy scientist and first director of the Atomic Energy Commission's Reactor Development div., succeeds Charles L. McCuen as a vice-president of General Motors Corp. He serves also as director of the research staff of the company.

Otto H. York Co., Inc., announces appointment of **Edward G. Scheibel** as director of engineering. He will be responsible for design and development of chemical process equipment with emphasis on extraction, distillation and mist eliminating equipment.

Edwin M. Haun named inorganic development manager for Monsanto Chemical Co's. overseas div. Haun, assuming his duties since October 1st, will take over development liaison between his div. and the inorganic chemicals div. of the company, and with evaluation of expansion possibilities for inorganic activities overseas.

Paul W. Bachman elected vice-president and director of research and development for Koppers Co., Inc. Bachman, will be responsible for development of research policies and objectives.

Arthur Ralph Winters joins General Electric Co.'s capacitor dept. as process engineer. He will work in the Hudson Falls, N. Y. plant.

Carlton L. Horine joins development dept. of Brea Chemicals, Inc., as senior process engineer.

Shelby A. Miller from professor of chemical engineering at the U. of Kansas to professor and chairman of the Dept. of Chemical Engineering, U. of Rochester.

W. L. Bulkley heads equipment development section, equipment div. of Standard Oil Co. (Indiana).

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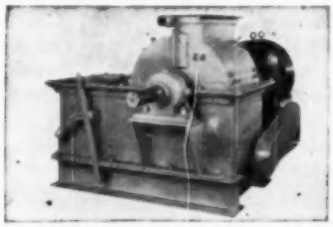

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Used to prepare *filter aids* and for preparing *pulps* for *diffusions* and *extractions*. For reclaiming and refining *wood wastes, agricultural fibres, bagasse, straw, flax, cotton linters* and the like.

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Julian M. Avery named director of product development div. of Ethyl Corp. Avery, an Ethyl consultant before joining the company in 1952, will retain his duties as technical advisor in addition to his new position.

Carbide and Carbon Chemicals Co. appoints **George Trigaux** asst. product manager, fine chemicals div. **J. M. Cole** and **J. H. Mathewson** take over as product managers.

Thomas B. Nantz appointed general manager of plants for B. F. Goodrich Chemical Co. **Walter E. Brodine** to plant manager at Calver City plant succeeding Nantz. Added to the company staff are **Emin I. Arsan, Dwight M. Wever, Ray V. Mihailovich, Robert J. Minchak,** and **Robert F. Singer,** all to the research center.

Minnesota Mining & Manufacturing Co. announces promotions: **John R. Favorite** to technical director, duplicating products div.; **William R. Ludka,** manager, engineering research dept., and **Robert C. Anderson,** manager, staff labs engineering dept.

Russell L. Bauer appointed chief engineer of Mead Johnson & Co. Bauer's responsibilities include direction and development of Mead plant facilities and activities.

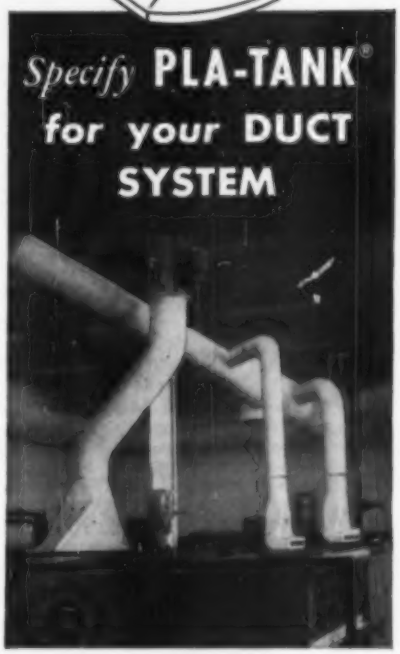
Samuel Lenher and **David H. Dawson** elected vice-presidents and members of the executive committee, Dupont. Lenher replaces **Roger Williams,** "one of the nation's most distinguished industrial scientists," who recently retired from the company. Dawson will serve also as a director of the company.

S. H. McAllister, assoc. director of research in the research center, Shell Development Co., appointed director of the company's agricultural research div., Denver. Shell announces also the appointment of **Fred Condo** as asst. dept. head of the polymer and chemical applications dept.

Frederic de Hoffmann appointed vice-president, General Dynamics Corp. He will serve as general manager of the corporation's general atomic div.

Chas. Pfizer & Co., Inc., names **Robert C. Ottke** manager, development section. **John K. Shaw** will manage industrial section.

FROM RAINCAP TO HOOD



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Included in the system (in addition to hoods, ducts, stacks and caps) are molded PLA-TANK fan housings and propeller-type fan blades. *Everything that contacts the fumes is molded of chemical-resistant PLA-TANK.*

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the chemical engineer in MARKETING

F. D. Parker, former manager of the chemical plants div. of Blaw-Knox Co., named vice-president-engineering of the petroleum div. of Arthur G. McKee & Co. Parker, pictured will take part in expanded activities in the petroleum and petrochemical fields. **H. G. Boucher** is new sales engineer in petroleum div. He will headquarter in New York.

George F. Clifford, Jr. is newly-appointed sales manager of the Spinco div. of Beckman Instruments, Inc. Clifford to work with merchandising of Spinco ultracentrifuges and electrophoresis apparatus. He was sales manager for International Equipment Co., Boston.

General Ceramics names **John P. Walsh** sales engineer for pyrotone welding backing rings. He will handle sales and service of the product.

Wyandotte Chemicals Corp. organizes three new divisions: **Bert Cremers** heads Michigan alkali div. as vice-president and general manager; **Frank B. Wolcott** takes over expanded development and marketing activities of research and engineering div.; and **George W. Schwarz** heads general products div. as vice-president and general manager.

Charles E. Webb, asst. to the general manager of the Sharples chemicals div. of Pennsylvania Salt Manufacturing Co., named manager of services at the division's Wyandotte, Mich. plant.

Thomas R. Darmody named asst. general manager of Vitro Engineering div. of Vitro Corp. of America. He will work from the New York office of the company.

David T. Marvel, a vice-president of Olin Mathieson Chemical Corp., named vice-president in charge of sales of the metals div.

Thomas M. O'Neil elected vice-president in charge of sales and marketing for Heyden Chemical Corp. He will continue also as vice-president of Nuodex sales and marketing.

(*Continued on page* 121)

CLASSIFIED SECTION

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TWO SALES ENGINEERS

One man to sell complete processing units to produce ammonium nitrate, nitrophosphates, and other fertilizer materials. Must be graduate engineer with sales experience on chemical plant equipment. Work is part office, part travel, some abroad.

One man to sell equipment for grinding, classifying and collecting sub-sieve size powders. Should know this trade thoroughly. Must be graduate engineer, and have record of success in selling. Immediate opportunity to head new department of the company.

Philadelphia company with fine reputation in U. S. and abroad. Liberal bonuses, hospitalization, pension, etc.

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If you are interested in any of the above positions, would you please write, giving full information as to experience, education, salary desired and other information, to Lewis J. Ringler, Industrial Relations Department, The Sherwin-Williams Company, 101 Prospect Avenue, N.W., Cleveland 1, Ohio.

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This opening requires five years' general industrial experience and a thorough knowledge of theory and practice in the field of agitation.

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The duties of the position will require a broad and detailed knowledge of mechanical drying equipment and their applications. The position requires a high level of creativeness and skill in evolving unorthodox solutions to practical problems in drying.

WATER

The desirable background will include extensive experience in water procurement and treatment for industrial plants. Knowledge of water treatment plant operation through practical experience is important.

The successful applicant will provide engineering advice to those designing, constructing, and operating company plants on problems involved in the procurement and treatment of industrial water supplies.

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Position requires an educational background combining an extensive program of study in engineering with heavy emphasis on mathematics or applied statistics.

The successful applicant will be assigned to a new company-wide Operations Analysis Group, the activities of which include: programming electronic computers; mathematical formulation of scientific problems and a broad variety of business and management problems; and applied statistics, such as process analysis, quality control, and the design and analysis of experiments.

HEAT TRANSFER

Position requires a minimum of five years' engineering experience, including at least three years in the field of heat transfer.

The successful applicant will be well grounded in engineering fundamentals and in higher mathematics. He will provide engineering consultation in the specialized field of heat transfer as applied in the chemical industry. His work will require solution of complex problems encountered by research, design, and operating groups.

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Position requires a graduate chemical, electrical, or mechanical engineer experienced in research, application, consulting, or design of automatic controls for chemical, mechanical, or aeronautical applications.

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CHEMICAL ENGINEER—M.S.Ch.E. experienced in petroleum plant technical service wishes to locate in New York, New Jersey or Connecticut. Presently employed by major oil company. Columbia graduate, 1948. Desires technical service or design work in petrochemicals. Box 9-10.

CHEMICAL EXECUTIVE—Broad industrial and executive experience heavy inorganics, electrochemistry, phosphates, rare and nuclear metals, potash, special organics—general manager, research director, consultation. Advanced degrees engineering, organic, inorganic; professional engineering registration. Box 10-10.

CHEMICAL ENGINEER—M.S. Supervisory and administrative ability, sound and varied technical background. Twelve years' successful experience in research, design and production functions. Creative, competent, loyal, a self-starter who can follow through. Desire responsible position with opportunity for growth in management. Box 11-10.

REGISTERED CHEMICAL ENGINEER with seventeen years' experience in the design, construction and operation of plants to produce salt, bromine, insecticides, pharmaceuticals, etc. Five years' experience with large engineering firm in industrial and commercial building design, specifications, cost analysis, plant surveys. Present earnings $12,000. Desires executive engineering position with multi plant organization. Box 12-10.

CHIEF ENGINEER—Chemical engineering background, age 40. Presently full charge of 1,000 man engineering department in large chemical plant, directing all phases of design, power and maintenance. Extensive experience both foreign and domestic. Speciality, developing engineering organizations. Box 13-10.

CHEMICAL ENGINEER—Ph.D. Age 36. Fourteen years' varied and responsible experience—industrial research, development, design, sales and administrative assignments; academic research, teaching, consulting—Chem., Met. and AEC fields. Desire responsible administrative position requiring broad background. Box 14-10.

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CHEMICAL ENGINEER—B.S.Ch.E. 1943—Licensed. Twelve years' diversified experience in petrochemical processing with operating and engineering companies. All phases plant startup, operator training, process improvement, cost reduction, cost estimating, economics. Proven ability to plan, organize, direct plant operations. Desires challenging position in production management in expanding company in Florida, Miss., Louisiana Gulf Coast. Age 34, married, family, employed. Box 23-10.

CHEMICAL ENGINEER—B.S.Ch.E., age 29. Over eight years' unusually diversified project engineering including economics, justification, general design calcs, trouble shooting, contracting, erection, startup, etc. Seeking challenge and growth in diversified consulting or central engineering Chicago area. Box 24-10.

CHEMICAL ENGINEER—M.Ch.E. Age 34, married. Eleven years' experience in food field (research, pilot plant, production supervision, technical service, plant design and construction). Desire challenging position with growing food or chemical company. Future in production management. Permanence. Available December. Box 16-10.

CHEMICAL ENGINEER—M.S., age 35. Diversified experience including process design, economics of petrochemical and petroleum processes. Desire responsible position in process engineering or other challenging opportunity. Prefer Southwestern or Southern location. Box 17-10.

CHEMICAL ENGINEER—Age 27, M.I.T., M.S., Chem. Eng., B.S., Business & Eng. Admin. Leave Army November. Experience nine months cost analysis, seventeen months pilot plant operation and process development. Looking for opportunity to use my teaching in both engineering and administration. Box 18-10.

TECHNICAL EXECUTIVE—CHEMICAL ENGINEER—M.S.Ch.E. Age 45, twenty-two years' varied experience chemical and radiological research and development; and production. Thirteen years' successful atomic research and development. Seeks greater opportunity and responsibility. Challenging position with future desired. Box 19-10.

CHEMICAL ENGINEER—M.Ch.E., age 29, some experience, draft exempt, seeking position in research or development fully utilizing engineering training. Location: Metropolitan New York. Box 20-10.

CHEMICAL ENGINEER—Age 28, married, veteran, B.Ch.E. 1951. Four and one-half years' experience in plant engineering and maintenance work. Desire position offering opportunity and responsibility. Box 21-10.

ENGINEER—B.S.Ch.E., 1953, from five-year Co-op program; Tau Bate; Two years (plus 1½ years Co-op) experience in semiworks scale process development; unsatisfied with present situation; available in December; interested in sales-marketing, production or research-development opportunities but not in dead ends; prefer Boston area but others considered; salary desired, $6600. Box 22-10.

CHEMICAL ENGINEER—B.S.Ch.E. plus graduate study. Age 31. One and a half years' experience in heat transfer analysis and two years group leader of process design group. Desire position in process design and analysis. Box 25-10.

CHEMICAL ENGINEER—Age 34, S.B. 1942. Ten years' experience as project engineer and construction superintendent, electrolytic cells a speciality, speaks Spanish and French, seeks position of engineering or administrative responsibility in small progressive concern. Box 26-10.

CHEMICAL ENGINEER—M.S., age 35; desires challenging executive position. Nine years of diversified experience in chemicals: process and product development, pilot plant engineering and plant supervision and consultation. Cost and safety conscious. Married, veteran. Box 27-10.

PRODUCTION ENGINEER—M.Ch.E. Age 37. Recognized thirteen year record of accomplishments in plant and process engineering, trouble-shooting, assistant to vice-president charge of production, chief engineer for multi-plant organization, plant manager of fermentation alcohol plant. Seeking responsible position in production, engineering or management. Box 29-10.

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INDUSTRIOUS ENGINEER—Desires productive employment. B.S.Ch.E., 1950. Age 30. Five years' experience in design and manufacture of oil and gas process equipment. Box 28-10.

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

the chemical engineer in

MARKETING

(*Continued from page* 116)

Warren E. Hesler takes over new sales and service office of the Rodney Hunt Machine Co. located in the Grand Central area, New York. Hesler will be available for consultation on turba-film evaporators, luwa spray dryers and other process equipment offered through the company.

William T. Rossiter, Jr. appointed manager of leather and textile sales for Dow Corning Corp. Rossiter, with the company since 1950, will work especially in Dow's program to increase promotion of silicones to the leather and textile industry.

Clifford A. Hampel joins Fansteel Metallurgical Corp. as manager of chemical equipment div. with responsibility for engineering, design and sales of products to chemical process industries.

The Norton Company names **Warren L. Hardy** business research manager. Succeeding **Myron N. Smith** who recently retired after 40 years with the company, Hardy brings with him experience of several years in sales engineering and business analysis and research.

Kinney Manufacturing div. of the New York Air Brake Co. names three sales engineers: **Arthur J. Shivers, Jr.,** Philadelphia office; **Jackson A. Brower,** New York district; and **Thomas A. Sowin,** Chicago headquarters.

Project engineer **Hubert J. Thomiszer** named manager of Magnilastic div. of Cook Electric Co. He has served in the Cook Research Labs and with Armour Research Foundation.

Richmond M. Stampley appointed Western Filtration div. manager for Dorr-Oliver, Inc. He takes over marketing of all company filtration equipment in 11 western states. Stampley headquarters in Oakland, Calif.

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news and notes

EAST TENNESSEE SECTION recently inaugurated a news letter, which covers meetings, gossip of the local section, appointments to committees, etc., of local members . . . Quite a number of local sections are using these informal news letters to keep membership interest at a high point.

NORTHERN CALIFORNIA SECTION is putting its weight behind a move to increase the interest of students in their professional society . . . The section sponsors an annual award to two superior senior students, one at the University of California & one at Stanford University . . . The award includes the A.I.Ch.E. entrance fee, an emblem, & one year's dues for Associate membership.

NEW JERSEY SECTION has also adopted young graduates from universities . . . The section makes an award to the top graduating chemical engineers from Princeton University & from Newark College of Engineering . . . Award consists of a Certificate of Merit and payment of the initiation fee & first year's dues as Associate Member of A.I.Ch.E. . . . This year awards went to Olev Trass of Princeton & Lionel Sirois of Newark College of Engineering.

ROCHESTER SECTION has hit on a good public-relations device with the speakers who address the section during the year . . . At the conclusion of each season speakers are presented with a memento of the occasion.

RESEARCH COMMITTEE is beginning its fourth year of work on plate efficiencies & fractionating towers . . . this year to be one of the most intense as far as research is concerned . . . Report of progress up to date has been completed & issued to the sponsors, committee members, members of Council, & accredited schools . . . Report is a summary written by Professor J. A. Gerster of the University of Delaware, one of the schools doing the research . . . To put it technically from a report by Howard Malakoff, chairman of the Research Committee this year, status to date ". . . can be summarized by stating that 1) the effects of tray efficiency on gas rate, liquid rate, liquid holdup on the tray, & column pressure have been determined & 2) progress has been made in determining the manner in which the measured mass transfer phase resistances vary with physical properties of the system & in predicting over-all tray efficiencies by addition of these individual gas & liquid phase resistances" . . . For 1955-1956 the committee research budget has been raised to $100,000 from $80,000 in the past year.

STUDENT CHAPTER COUNSELORS . . . New chapter counselor at the University of British Columbia is Norman Epstein; at the University of Michigan, Kenneth F. Gordon; University of Southern California, Joseph S. Smatko; University of Texas, Thomas K. Perkins; University of Toledo, Walter V. Burg.

PROGRAMS OF THE INSTITUTE'S DETROIT MEETING & the preliminary program for the Nuclear Engineering & Science Congress will be in the mail, possibly in your hands, before you read this . . . This will be for the Institute the largest program mailing ever . . . A.I.Ch.E., which is also headquarters for preprints for the Nuclear Congress, has up to this point printed for the E.J.C. Congress some 200,000 copies of a preliminary announcement and 175,000 copies of the preliminary Nuclear Congress program.

ELECTION BALLOTS for officers & directors are also being mailed . . . Dues bills, membership cards, directory mailing information will be mailed too during the month of October.

STUDENT CHAPTER NEWS, according to James G. Knudsen & Charles E. Wicks, who were coeditors this year, had an interesting season . . . Forty-seven chapters of the Institute subscribed this year, with proportionately more students than ever before in each chapter receiving this special publication.

MEMBERSHIP DRIVE is pushing ahead . . . Latest section to make a special effort is New York, which is announcing a contest . . . This will be on an individual-members basis: the section member bringing the most new members to the national A.I.Ch.E. during the year will receive a prize . . . Chairman of the drive is A. G. Parker of the Foster Wheeler Corporation.

F.J.V.A.

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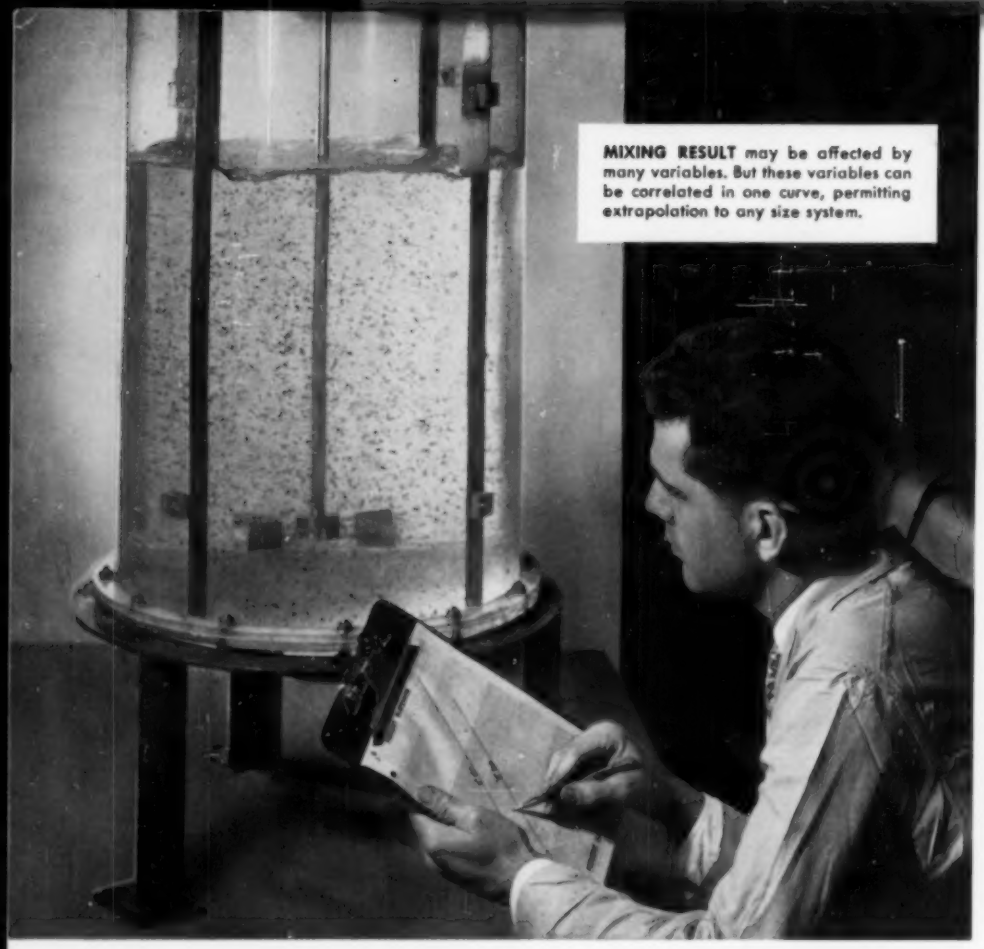

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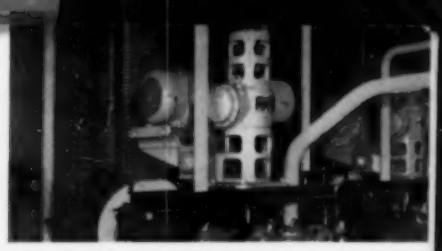

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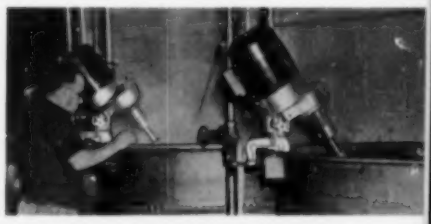

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- ☐ B-107 Mixing Data Sheet
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